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Arnold Krochmal
Russell S. Walters
Richard M. Doughty

A Guide to MEDICINAL PLANTS of Appalachia

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THE AUTHORS

ARNOLD KROCHMAL graduated from North Carolina State College in 1942; he received his master's degree in 1951 and his Ph.D. in 1952 from Cornell University in economic botany, with a minor in plant physiology. As a Fulbright professor, he worked in Greece, and has also served in Afghanistan, Honduras, and the U.S. Virgin Islands. He also served as a consultant in Thailand, the Dominican Republic, British Virgin Islands, Jamaica, Montserrat, and Surinam. In 1966 he joined the Forest Service's Northeastern Forest Experiment Station as project leader and principal economic botanist in charge of the Station's timber related crops program, located at Berea, Kentucky.

RUSSELL S. WALTERS graduated from Michigan State University in 1951; he received a master's degree in forest management, with a minor in range management, from Oregon State University in 1953. He began his Forest Service career in 1955 at Carbondale, Illinois. Later that same year, he became superintendent of the Vinton Furnace Experimental Forest in Ohio. In 1958, he was transferred to Athens, Ohio, where he specialized in forest management and silvicultural research for the Forest Service. He is now working with the timber related crops program at Berea, a position he took in 1964.

RICHARD M. DOUGHTY earned his bachelor's and master's degrees in botany at the University of Pittsburgh. He has also done graduate work at Indiana University. In 1951, he joined the staff of the University of Kentucky College of Pharmacy, as instructor in pharmacognosy, the science of drugs from natural sources. He is now chairman of the Materia Medica Department at this University. Professor Doughty also gives lectures on natural products, poisonous plants, herbs, and spices.

A Guide to MEDICINAL PLANTS of Appalachia

FOREWORD

THE MEDICINAL or therapeutic uses of the plants described in this guide are not to be construed in any way as a recommendation by the authors or the U.S. Department of Agriculture. Some of the dried crude drugs, which must be modified considerably before commercial use, can be extremely poisonous when not used properly. Readers are cautioned against using these plant drugs for purposes of self-medication.

Besides descriptions of 126 medicinal plants of the Appalachian region, this guide includes a glossary of the terms used, a reference list of publications, and a listing of additional source material.

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INTRODUCTION

DESPITE INCREASES in the production of synthetic drugs, natural plant drug materials are still economically significant in the United States, and large quantities are harvested in the southern Appalachian region each year for medicinal purposes. A 1962 survey of 328,599,000 new prescriptions written in the U. S. showed that 25 percent were for drugs from natural plant products.

However, during the past 30 to 50 years, fewer and fewer people have been harvesting wild plants in Appalachia, which is the principal American source, mainly because of families emigrating to more prosperous areas. Between 1950 and 1960, the southern Appalachian region lost through emigration more than a million people, nearly a fifth of the population. Increases in local blue-collar employment opportunities, a growing reluctance to work in the fields and forests, scarcity of some plants because of over-collecting, and land-use changes have also reduced the natural plant harvests for drug materials.

To locate, collect, and prepare plants for market is time-consuming work. Some collectors do not know all the useful plant species and the best markets for them. This manual was prepared to help collectors identify, collect, and handle plants, plant parts, and pollen.

Not all the plants listed are marketable at all times; so the collector would do well to write to one of the collecting houses listed (table 1) for prices and information about market demand. Buyers of such material are helpful in providing other useful information on collecting.

Table 1.—Names and addresses of buying houses*

Names	Addresses
PURCHASERS OF BOTANICALS	
Blue Ridge Drug Company	P. O. Box 234, West Jefferson, North Carolina 28694.
Coeburn Produce Company	Second and Grand Streets, Coeburn, Virginia 24230.
C. R. Graybeal	Roan Mountain, Tennessee 37687.
F. C. Taylor Fur Company	227 E. Market Street, Louisville, Kentucky 40202.
Greer & Greer	Box 307, Princeton, West Virginia 24740.
Greer Drug & Chemical Company	P. O. Box 800, Lenoir, North Carolina 28645.
Nature's Herb Company	281 Ellis Street, San Francisco, California 90025.
Old Fashioned Herb Company	581 N. Lake Avenue, San Francisco, California 90025.
Smoky Mountain Drug Company	935 Shelby Street, Box 2, Bristol, Tennessee 37620.
Wilcox Drug Company	P. O. Box 391, Boone, North Carolina 28607.
Wilcox Drug Company, Inc.	Box 470, Pikeville, Kentucky 41501.
IMPORTERS THAT BUY, SELL, AND PROCESS BOTANICALS	
Hathaway Allied Products	2024 Westgate Avenue, Los Angeles, California 90025.
S. B. Penick & Company	100 Church Street, New York, New York 10007.
VENDORS OF DRUG AND HERB SEED AND OTHER PROPAGATING MATERIALS	
Gardens of the Blue Ridge	Ashford, North Carolina 28603.
Harry E. Saier	Dimondale, Michigan 48821.
Indiana Botanic Gardens	P. O. Box 5, Hammond, Indiana 26325.

*These firms are mentioned for information only, and this mention should not be considered as an endorsement or recommendation by the U.S. Department of Agriculture or the Forest Service.

PLANT DESCRIPTIONS

Identification

To help the collector identify plants, brief descriptions are given in this guide. Some closely related plants, such as *Lobelia* (Indian tobacco), are difficult to identify before the seed capsules have developed; so as a further aid in identification, sketches or photos accompany every plant description.

A collector who wants to identify a plant known only by a common name should locate that name in the index and then refer back to the descriptions and illustrations to identify the plant. If the same common name is applied to more than one plant, this will be shown by the page numbers next to the common name in the index.

Names

Plant names can be confusing. A plant may have many common names, and the same common name may be applied to several unrelated plants. We have tried to show as many common names as possible, listing first the preferred common name suggested by the Subcommittee on Standardization of Common and Botanical Names of Weeds. If this list did not include names for a plant, we used *Standardized Plant Names.* Other references used were *Flora of West Virginia, Manual of Cultivated Plants, Flora of the Northeastern United States,* and State experiment station bulletins.

Scientific names are also given to simplify proper identification of plants. Although a number of common names may be in use for a given plant, only one scientific name is used.

COLLECTING PLANTS

Time of Year

It is important to collect at the time of the year when the drug contents of the plants are at their peak.

Roots are collected either very early in the spring before growth has begun, or late in the fall. Herbs (the part of the plant above ground) are usually collected during the blooming-fruiting period. Leaves are usually collected before blooming begins and can either be removed from the plant in the field, or the plants can be harvested and the leaves can be removed later at a collection area. Seeds and fruits are best harvested when ripe. Bark should be collected when it slips most easily, during the dormant season or in early spring.

The parts of each plant collected are shown in table 2.

Table 2.—The parts of plants collected

B = Bark.
BR = Bark of root.
BU = Buds.
EP = Entire plant.
F = Fruit.
FL = Flowering top.
H = Herb.
J/S = Juice or sap.
L = Leaves.
RR = Roots, rhizome.
SE = Seeds.
ST = Stalk.
T = Twigs.

Plant	Part collected												
	B	BR	BU	EP	F	FL	H	J/S	L	RR	SE	ST	T
1. *Acer spicatum* Lam.	X												
2. *Achillea millefolium* L.							X						
3. *Acorus calamus* L.										X			
4. *Adiantum capillus-veneris* L.									X	X			
5. *Adiantum pedatum* L.							X						
6. *Aesculus hippocastanum* L.	X				X								
7. *Aletris farinosa* L.										X			
8. *Alnus serrulata* (Ait.) Willd.	X												
9. *Amaranthus hybridus* L.							X		X				
10. *Angelica atropurpurea* L.							X			X	X		
11. *Aplectrum hyemale* (Muhl.) Torr.										X			
12. *Apocynum androsaemifolium* L.										X			
13. *Apocynum cannabinum* L.										X			
14. *Aralia nudiculis* L.										X			
15. *Aralia racemosa* L.										X			
16. *Arctium lappa* L.										X	X		
17. *Arctium minus* (Hill) Bernh.										X	X		
18. *Arisaema triphyllum* (L) Schott										X			
19. *Aristolochia serpentaria* L.										X			
20. *Asarum canadense* L.									X	X			
21. *Asclepias syriaca* L.									X	X			
22. *Asclepias tuberosa L.*										X			
23. *Baptisia tinctoria* (L.) R. Br.		X					X			X			

CONTINUED

Table 2—Continued

Plant	Part collected											
	B	BR	BU	EP	F	FL	H	J/S	L	RR	SE	ST	T
24. *Berberis vulgaris* L.	x	x			x					x			
25. *Betula lenta* L.									x				
26. *Caulophyllum thalictroides* (L).										x			
27. *Ceanothus americanus* L.		x							x	x			
28. *Chamaelirium luteum* (L) Gray										x			
29. *Chelone glabra* L.							x						
30. *Chenopodium ambrosioides* L.				x	x						x		
31. *Chimaphila maculata* (L.) Pursh.									x				
32. *Chimaphila umbellata* (L.) Bart.				x					x				
33. *Chionanthus virginicus* L.	x	x											
34. *Cimicifuga americana* Michx.										x			
35. *Cimicifuga racemosa* (L.) Nutt.										x			
36. *Cnicus benedictus* L.							x				x		
37. *Collinsonia canadensis* L.							x			x			
38. *Comptonia peregrina* (L.) Coult.									x				
39. *Corallorhiza* spp.										x			
40. *Cypripedium calcelous* L.										x			
41. *Datura stramonium* L.									x		x	x	
42. *Dioscorea villosa* L.										x			
43. *Echinacea purpurea* (L) Moench.										x			
44. *Eryngium aquaticum* L.										x			
45. *Euonymus atropurpureus* Jacq.	x	x											
46. *Eupatorium perfoliatum* L.						x	x		x				
47. *Eupatorium purpureum* L.						x			x	x			
48. *Fragaria virginiana* Duch.					x				x				
49. *Fraxinus americana* L.	x												
50. *Galium aparine* L.							x						

51. *Gaultheria procumbens* L. . . . . x . . . . . .
52. *Gelsemium sempervirens* (L) Ait. . . . . x . . . . . .
53. *Gentiana villosa* L. . . . . x . . . . . .
54. *Geranium maculatum* L. . . . . x . . x . . . . . .
55. *Hamamelis virginiana* L. . . . . x . . . . . x x
56. *Hedeoma pulegioides* (L.) Pers. . . . . x . . . . . .
57. *Hepatica acutiloba* (D.C.) . . . . . x . . . . . .
58. *Hydrangea arborescens* L. . . . . x . . . . . .
59. *Hydrastis canadensis* L. . . . . x . . . . x . . . . . .
60. *Jeffersonia diphylla* (L.) Pers. . . . . x . . . . . .
61. *Juglans cinerea* L. . . . . x . . . . . x . . . . . x . . . . . .
62. *Juglans nigra* L. . . . . x . . . . . x . . . . . x . . . . . .
63. *Juniperus communis* L. . . . . x . . . . . .
64. *Juniperus virginiana* L. . . . . x . . . . . .
65. *Lactuca scariola* L. . . . . x . . x . . . . . .
66. *Leonuris cardiaca* L. . . . . x . . . . . .
67. *Lindera benzoin* (L) Blume . . . x x
68. *Liquidambar styraciflua* L. . . . x . . . . . x . . . . . .
69. *Lobelia inflata* L. . . . . x . . . . . .
70. *Lycopus virginicus* L. . . . . x . . . . . .
71. *Marrubium vulgare* L. . . . . x . . . . . x . . .
72. *Menispermum canadense* L. . . . . x . . . . . .
73. *Mentha piperita* L. . . . . x . . . . . .
74. *Mentha spicata* L. . . . . x . . . . . x . . . . . .
75. *Mitchella repens* L. . . . . x . . . . . .
76. *Monarda didyma* L. . . . . x . . x . . . . . .
77. *Myrica cerifera* L. . . . . x . . x . . . . . x . . x . . . . . .

CONTINUED

Table 2—Continued

Plant	Part collected											
	B	BR	BU	EP	F	FL	H	J/S	L	RR	SE	ST	T
78. *Nasturtium officinale* R. Br.							X						
79. *Nepeta cataria* L.						X	X						
80. *Panax quinquefolium* L.										X			
81. *Passiflora incarnata* L.					X	X	X			X			
82. *Phytolacca americana* L.					X			X	X	X			
83. *Pinus palustris* Mill.								X					
84. *Pinus strobus* L.	X		X					X					
85. *Plantago* spp.									X		X		
86. *Podophyllum peltatum* L.										X			
87. *Polygala senega* L.										X			
88. *Polygonatum biflorum* (Walt.) Ell.										X			
89. *Polygonum hydropiper* L.							X						
90. *Populus balsamifera* L.	X		X										
91. *Prunella vulgaris* L.							X						
92. *Prunus serotina* Ehrh.	X												
93. *Quercus alba* L.	X												
94. *Rhus glabra* L.	X	X			X				X	X			
95. *Rubus* spp. L.	X	X			X				X	X			
96. *Rumex crispus* L.										X			
97. *Salix alba* L.	X		X										
98. *Salix nigra* (Marsh)	X		X										
99. *Salvia officinalis* L.							X						
100. *Sanguinaria canadensis* L.										X			
101. *Sassafras albidum* (Nutt) Nels.		X							X				
102. *Scrophularia marilandica* L.								X			X		
103. *Scutellaria lateriflora* L.								X					
104. *Senecio aureus* (L)							X			X	X		

105. *Solanum carolinense* (L)
106. *Sorbus americana* Marsh.
107. *Spigelia marilandica* L.
108. *Stellaria media* (L) Cyrillo
109. *Stillingia sylvatica* L.
110. *Tanacetum vulgare* L.
111. *Tephrosia virginiana* (L) Pers.
112. *Tiarella cordifolia* L.
113. *Trifolium pratense* L.
114. *Trilisa odoratissima* (Walt.) Cass.
115. *Trillium erectum* L.
116. *Tsuga canadensis* (L) Carr.
117. *Ulmus rubra* Muhl.
118. *Veratrum viride* (Ait.)
119. *Verbascum thapsus* L.
120. *Verbena hastata* L.
121. *Veronicastrum virginicum* (L) Farw.
122. *Viburnum nudum* (L).
123. *Viburnum prunifolium* L.
124. *Xanthorhiza simplicissima* (Marsh.)
125. *Xanthoxylum americanum* Mill.
126. *Xanthoxylum clava-herculis* L.

Only four plants are listed from which sap is collected. *Lactuca scariola* provides a milky juice; the plants are collected in summer for extracting the juice from the stems. The other three are trees. *Liquidambar styraciflua* (sweetgum) exudes balsam into natural pockets between the bark and the wood. Excrescences on the bark are cut for collecting the sap. *Tsuga canadensis* (hemlock) produces an exudate of resin, which occurs on the stem in reddish brown, opaque, or translucent pieces. *Pinus palustris* (long-leaf pine) is a source of turpentine, pine oil, tar, pitch, and rosin.

Collectors are urged to leave enough plants growing in each locality to conserve the plant population for future years.

Areas

The most likely areas where each plant may be found are listed. Time and effort can be saved by narrowing areas of search to those habitats where the plant usually occurs. Residents of a region can often provide information about growing areas. Care should be taken to respect property rights of landowners, and permission should be obtained before entering private land. State and Federal laws regarding plant collecting should be checked for given localities.

Tools

A wide range of tools—from a pocket knife to shovels of one type or another (fig. 1)—can be used by the collector, depending on what plant parts are to be harvested. For example, a shovel or an asparagus knife would be needed to harvest roots—plus a pair of shears to cut the tops. Bark collectors need a sharp knife, the size depending on the thickness of the material to be harvested.

As the collector gains experience, he will be able to determine exactly what tools are required for each kind of material. However, he will always want to carry the minimum number needed. All tools should, of course, be kept oiled and sharp; and they should be cleaned after each use.

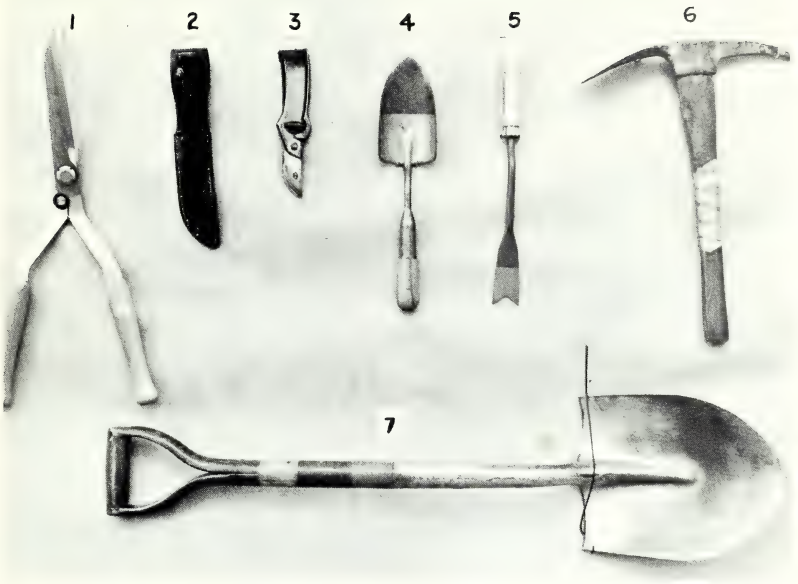

Figure 1.—Harvesting implements: (1) hedge clippers, (2) sheath knife, (3) pruning shears, (4) trowel, (5) asparagus digger, (6) pick, and (7) shovel.

PROCESSING

Cleaning

Cleaning harvested plant materials is called *garbling*. It includes removal of stones, soil, and unwanted plants and plant parts. Roots and underground parts may have to be washed if soil clings to them.

Drying

Rapid drying is needed to preserve green color, to reduce spoilage and molding, to reduce or stop enzyme action that destroys drug constituents of plants, and to make the materials more compact for shipping. This is important because improper drying can result in reduced value, if not complete loss of the material collected.

Two methods are used to dry drug plants. The natural method is the simpler; it makes use of natural air temperature and air movement. The second method uses artificially heated and circulated air. Many different types of equipment are used. These range from simple and inexpensive tools for handling small quantities of a few kinds of plants to the large costly equipment needed for handling many kinds of plants in large lots.

Natural drying.—Natural drying uses the sun's heat plus shade and air movement. A porch or barn floor or almost any shaded area with a dry floor will do. Shallow wire-bottomed trays are cheap to make and can be used to good advantage (fig. 2). Too much exposure to the sun can cause loss of green color, thus decreasing the value and marketability of certain materials.

Figure 2.—Shallow wire-bottomed trays can be used for natural drying.

Artificial drying.—A simple and inexpensive drying box can be built for less than $25, using a standard home-type, fan-driven space heater (fig. 3). This box takes up less floor space than the natural drying method, dries plants more

quickly, and produces a more uniform product. Racks (fig. 4) provide space for drying all types of plant materials.

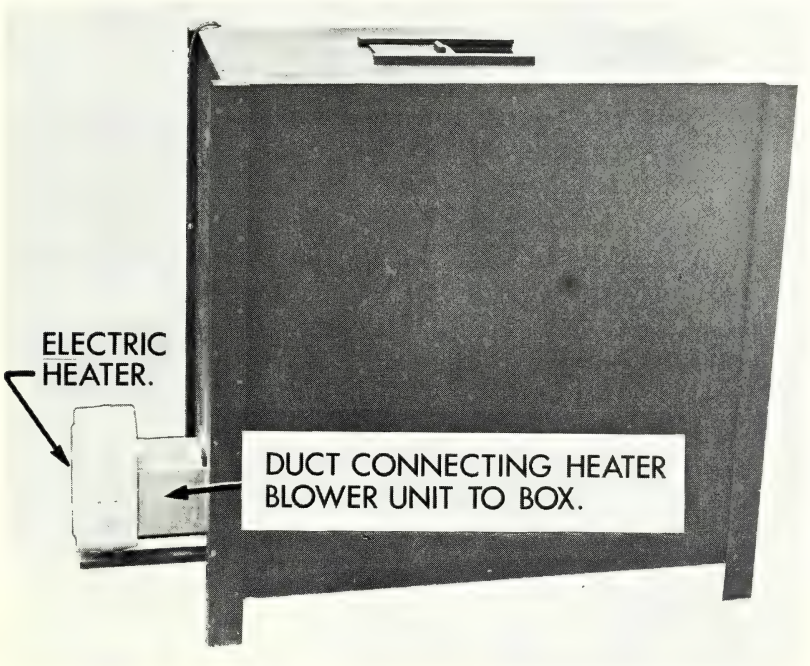

Figure 3.—A drying box, showing heating unit and duct; top shows sliding door used for air circulation.

Processing before drying.—Roots are usually sliced lengthwise or crosswise to hasten drying and to minimize spoilage and molding. (Ginseng roots are not sliced because their shape is important in meeting market demands.) Fleshy fruits, which are particularly apt to spoil, should be cut in halves or quarters and dried in a drying box. Bark can be cut into uniform pieces to hasten drying. Seeds should be spread in a fairly thin layer in aluminum or cardboard pie plates or similar available containers.

Figure 4.—Interior of an artificial drying box, showing drying racks.

Packaging and Storing

Clean burlap sacks, boxes, and paper sacks are all usable for packing dried plant material. Boxes should be dry and lined with clean paper. Collectors should avoid using plastic bags because any excess moisture present when the bags are shut may result in molding.

Plant material should be stored under sanitary conditions that minimize rodent and insect contamination. Clean, dry, ventilated storage areas are best for preserving quality, (fig. 5).

Figure 5.—A buyer of medicinal plants inspects a drying spikenard root.

COLLECTING POLLEN

Pollen is used by drug companies for making preparations to test for pollen allergies. Among the pollens most in demand are ragweeds, sages, magwort, sagebrush, elm, box elder, maple, ash, oak, cocklebur, pigweed, and Russian thistle.

Different kinds of pollen should not be mixed together because pollen buyers inspect shipments with a microscope, and any impure materials are rejected. Pollen should not be collected from plants that have been treated with pesticides.

Methods

The day before pollen is to be collected, tie several blooming heads together with white string to mark the plants wanted and to reduce loss from wind (fig. 6).

Pollen can be harvested from a plant for several days, but when the pollen begins to turn dark another plant should be used.

Harvesting can begin on clear mornings, as soon as the dew is gone; and, depending on the wind, harvesting can continue for about 2 hours. However, if the day is still, harvesting can continue longer.

Figure 6.—One way to collect pollen: roll the heads of the flowers gently over a catching cloth, spreading the blooms with your fingers to release the pollen.

Drying

Immediately after a day's harvesting is finished, the pollen should be spread out on clean, dry, brown wrapping paper (an opened grocery bag will do) in a warm, draft-free room. The pollen should be spread to a depth of about 1/4 inch and left to air-dry for 4 days. Mold may occur on the pollen if it is dried less than 4 days, and moldy pollen will not be accepted by buyers.

When dry, the pollen should be strained through fresh nylon or organdy, and packed in clean, dry, screw-top jars or in clean, dry, strong plastic bags.

Grass Pollen

Because pollen from grasses such as timothy, Johnson and others is difficult to collect in the field, a special harvesting technique has been worked out. As they mature heads of plants are harvested in the field and brought to a shed or protected areas. The stems are placed in a container of water and the pollen is collected on sheets of paper (fig. 7) placed next to the container. The pollen is then cleaned through nylon or organdy and packed for shipment.

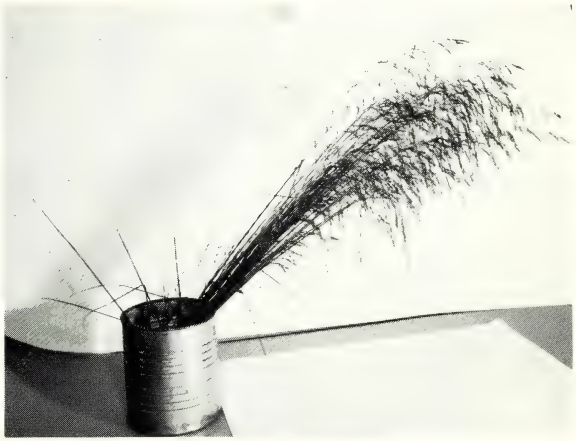

Figure 7.—Grass pollen is collected on sheets of paper after mature heads of plants have been harvested.

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GLOSSARY

Botanical and Pharmacological Terms

Acute. Sharp-pointed.
Ague. Old word for fever, usually malaria.
Allergenic. Produces allergy.
Alterative. Changes a condition gradually.
Ament. Catkin.
Annual. A plant that completes its development from germination of the seed through flowering and death in one growing season.
Anodyne. Relieves or quiets pain.
Antacid. Neutralizes excess acidity in the alimentary canal.
Anthelmintic. Capable of expelling or destroying intestinal worms.
Antiasthmatic. Relaxes bronchial muscles and relieves labored breathing.
Antidiarrheal. Counteracts diarrhea.
Antidote. Counteracts the action of a poison.
Antiemetic. Lessens the tendency to vomit.
Anti-infective. Prevents or inhibits infection.
Anti-inflammatory. Reduces inflammation and swelling.
Antinauseant. Stops or lessens the tendency to become nauseated.
Antipruritic. Prevents or relieves itching (antipsoriatic).
Antipyretic. Reduces fever.
Antirheumatic. Reduces pain in the joints.
Antiseptic. Checks or inhibits the growth of microorganisms.
Antispasmodic. Reduces spasm or prevents convulsion.
Antitussive. Relieves or prevents coughing.
Aquatic. Growing in water.
Aromatic. Agreeable, usually spicy, odor.
Astringent. Causes the contraction of tissue.
Axil. Angle between stem and leaf stalk.
Axis. Main line of growth.
Balsam. An aromatic substance produced in certain plants.
Basal. Occurring at the bottom.
Biennial. A plant that requires 2 growing seasons to complete its development from germination of the seed through flowering and death.
Bract. Modified leaf, often below a flower petal.
Branchlet. A small branch growing from a large branch or tree trunk.
Bristly. Having short, stiff hairs.
Bur. Prickly seed envelope such as that of burdock (*Arctium*).
Buttressed. With projecting parts, usually refers to trunk of trees such as Cypress.
Capsule. A closed container bearing seeds; also a dry fruit with more than one part.
Carcinogenic. Causing cancer.
Cardio. Referring to heart action.
Carminative. Used to relieve gas and colic.
Catarrhal. Related to inflammation of the respiratory tract.
Cathartic. Causes an evacuation of the bowel.
Catkin. A scaly, drooping spike of flowers, such as that of willow.

Caustic. Destroys tissue.
Central nervous depressant. Depresses central nervous system activity.
Central nervous stimulant. Increases central nervous system activity.
Cholagogue. Increases the flow of bile.
Clasping. Partly or wholly surrounding the stem.
Cleft. With a space or division in the middle.
Clover-like. With leaves in three parts.
Cluster. A number of similar flowers or fruits growing closely together.
Composite. Refers to a structure apparently simple but made up of several distinct parts.
Compound. Two or more similar parts of a plant, especially fruits or leaves, united together into one whole.
Constituent. A component.
Corm. An enlarged solid bulb-like stem, usually underground.
Corolla. Usually petals.
Corona. An appendage borne between corolla and stamens in some flowers.
Corrective. Used to correct or make more pleasant the action of other remedies, especially purgatives. (Now called flavoring.)
Counterirritant. Causes irritation of the surface of an area with the object of relieving a deep-seated congestion.
Creeping. Spreading over the ground or other surface.
Cumarin. A toxic white crystalline lactone found in many plants; used to make perfume and soap.
Cylindrical. Having the form of a cylinder.
Cyme. Broad, flat flower cluster.
Cytotoxic. Poisonous to cells.
Demulcent. Substance used to protect or soothe the mucous membrane.
Dental obtundant. Used to dull or soothe acute toothache.
Depurative. Removes impurities and waste materials and purifies the blood.
Detachable. Removable.
Diaphoretic. Used to increase perspiration.
Digestant. Aids in the digestion of foods.
Disinfectant. Destroys or inhibits the growth of harmful microorganisms.
Diuretic. Increases the volume of urine.
Dormant. Resting or non-vegetative stage, usually during winter.
Downy. Covered with soft hairs.
Drab. Dull brown, or gray.
Drupe. Fleshy seeded fruit with one seed enclosed in a stony cover; peach, apricot.
Dyspepsia. A disturbed digestive condition characterized by nausea, gas, and heartburn.
Ellipsoid. Solid with elliptical outline.
Elliptical. Shaped like an elongated circle.
Elongate. Stretched out.
Emetic. An agent that causes vomiting.
Emmenagogue. An agent that induces menstrual flow.
Emmolient. Used externally to soften the skin and protect it.
Enzyme. Organic substance causing chemical changes without undergoing any chance of its own.
Excrescence. An outgrowth or enlargement.

Expectorant. An agent that causes expulsion of mucous from respiratory tract.
Exudate. Discharge in layers or flakes.
Febrifuge. Reduces fever (antipyretic).
Flatulence. Stomach discomfort caused by gas.
Frond. Leaf of fern or palm.
Fungicide. An agent that destroys fungi.
Furrowed. Wrinkled, corrugated, grooved.
Garbling. Process of sorting out and cleaning the usable parts of plants.
Genera. Groups of related plants.
Habitat. Particular location where plant usually grows.
Hemostatic. An agent used to stop internal hemmorrhage.
Herbaceous. Dying down annually at onset of winter.
Herb. Leafy upper portion of plant, minus roots.
Humus. Organic portion of the soil, usually dark colored.
Husk. Outer covering of seed or fruits.
Hypnotic. An agent that induces sleep without delirium.
Incision. A sharp, narrow notch or separation, as in the margin of a leaf.
Insecticide. An agent that kills insects.
Intoxicant. An agent that produces mental confusion with subsequent loss of muscular control.
Irritant. Causes inflammation of, or stimulation to, the tissues.
Lanceolate. Much longer than broad; lance-shaped.
Lateral. Occurring on a side.
Laxative. A cathartic that causes a more or less normal evacuation of the bowel without griping or irritation.
Leaflet. Part of a compound leaf.
Leafstalk. Stem of a leaf.
Linear. Going in a straight line.
Lobe. Rounded part or segment of an organ, usually part of a leaf or petal.
Mucilaginous. Slimy.
Narcotic. An agent that relieves distress and induces sleep.
Nodding. Drooping.
Node. The often swollen point on a stem at which a leaf is joined.
Oblanceolate. Having the broadest part of a lanceolate body above the middle.
Oblong. Longer than broad.
Opposite. Situated in pairs on an axis, each being separated from the other by half the circumference of the axis.
Opthalmiatric. Used in the treatment of eye diseases.
Ovate. Resembling hen eggs split lengthwise.
Palmate. Resembling a hand with fingers spread.
Panicle. Loosely branched flower cluster, pyramidal shaped.
Parasiticide. An agent that destroys animal or vegetable parasites.
Pectoral. Usually an expectorant, used for diseases of the chest and lungs.
Perennial. Continuing or lasting for several years.
Petal. Usually colored part of a flower.
Petiole. Leafstalk.
Pod. A dry seed vessel or fruit.
Pollen. Shed by male flowers, usually yellow dust; male reproductive agent.

Protective. Used locally to protect and soothe the skin and mucous membranes.
Pungent. A sharp sensation as to taste, smell, feeling.
Purgative. Increases peristalsis (contraction of the bowel).
Pustulant. Causes severe irritation of the skin, especially the sweat glands, and results in pustule formation.
Raceme. An elongated axis bearing flowers on short stalks.
Reclining. Bent down.
Refrigerant. Allays thirst and gives a sensation of coolness to the body.
Resinous. Characteristic of resin, a solid to semi-solid yellowish brown plant substance.
Respiratory sedative. Used to allay coughs.
Respiratory stimulant. Stimulates the respiratory centers.
Rhizome. Underground stem.
Rhombic. Having the form of an equilateral parallelogram.
Rootstock. Rhizome.
Rosette. Leaves orginating from a center point, or short intermode, often close to the ground.
Ross. To remove coarse outer bark.
Rubifacient. Causes reddening and mild irritation of the skin.
Saprophyte. A plant living on dead or decaying plant material.
Scale. Small leaves or bracts.
Sedative. Used to quiet the individual.
Serrate. Saw-toothed margin of a leaf.
Sessile. Lacking a stalk, hence directly attached to a main stem or branch.
Sheath. A long or tubular structure surrounding a stem.
Sialagogue. Causes an increase in the flow of saliva.
Simple leaf. A leaf that is not divided into leaflets even though lobed.
Solitary. Borne alone.
Somnifacient. Produces sleep without delirium; a soporific.
Soporific. Tending to cause sleep.
Spike. Usually an axis bearing flowers without stalks.
Spiny. Bearing sharp-pointed prickles or woody bodies.
Stalk. Stem on which a leaf, flower, or other organ is attached.
Stimulant (cerebral). An agent that stimulates the activity of the cerebellum, especially the centers of reason, thought, etc.
Stimulant (general). A substance which increases general functional activity.
Stomachic. Stimulates appetite and increases secretion of digestive juices.
Strict. Straight and upright; few if any branches.
Subtend. Below and close to, such as a bract below a petal.
Sudorific. Increases perspiration.
Taeniafuge. A tapeworm expellant.
Taenicide. As agent that destroys tapeworms.
Taproot. A main root growing down, with small lateral roots.
Terminal. At the tip.
Tonic. Stimulates the restoration of tone to the muscles.
Toothed. Indented.
Trifoliate. Having three leaflets.
Tubular. Tube-shaped; hollow cylinder.
Tufted. Having small bunches of hair close together.
Twining. Twisting and winding.

Umbel. A flat-topped cluster of flowers arising from a common point.
Urinary antiseptic. Retards the growth of microorganisms in the urinary tract.
Vasoconstrictor. Narrows the passageway of the blood vessel.
Vermicide. An agent that destroys worms.
Vesicant. Causes irritation to the skin, resulting in blisters.
Viscous. Sticky and thick.
Vulnerary. An agent that promotes healing of open wounds.
Whorl. Three or more flowers or leaves at a node forming a circle.
Winged. Having wings, such as the thin dry extensions on a maple seed.

Meanings of Terms Used in Plant Names

Acutiloba. Having sharp lobes.
Alba. White.
Albidum. Whitish.
Ambrosioides. Fragrant, like ambrosia.
Americanus. American.
Androsaemifolium. Having leaves like those of Androsaemum.
Aparine. Bedstraw.
Arborescens. Tree-like.
Atropurpurea. Very dark purple.
Aureus. Gold.
Balsamifera. Producing balsam.
Benedictus. Blessed.
Benzoin. A plant of the laurel family.
Biflorum. Having two flowers.
Calamus. Reed.
Canadense. Of Canada.
Capillus veneris. Hair-like.
Cardiaca. Heart-like.
Carolinense. Of Carolina.
Cataria. Catnip.
Cerifera. Wax-producing.
Cinerea. Grayish.
Clava-Herculis. Hercules club.
Communis. In groups.
Cordifolia. Heart-shaped.
Crispus. Waved and twisted.
Didyma. In pairs.
Diphylla. Two-leaved.
Erectum. Erect.
Farinosa. Covered with whitish mealy powder.
Frondosa. Full of leaves.
Glabra. Smooth.
Hastata. Triangular halberd-shaped lobes.
Hippocastanum. Horse-chestnut.
Hybridus. Mixed or impure.
Hydropiper. Water pepper.
Hyemale. Of the winter evergreen.

Incarnata. Flesh-colored.
Inflata. Expanded.
Lappa. Bur-like.
Lateriflora. Having flowers on the side.
Lenta. Pliant, tough.
Luteum. Yellow.
Maculata. Spotted.
Marilandica. Of Maryland.
Medica. Middle.
Millefolium. Very many leaved.
Minus. Lesser or smaller.
Nigra. Black.
Nudicaulis. Naked-stemmed.
Nudum. Bare.
Odoratissima. Very fragrant.
Officinale. Used medically.
Palustris. Of swamps.
Parviflorum. Small-flowered.
Pedatum. Like a bird's foot.
Peltatum. Shield-shaped.
Peregrina. Traveling from a strange country.
Perfoliatum. Having pierced leaves.
Piperita. Peppery.
Pratense. Of meadows.
Procumbens. Flat, prostrate.
Prunifolium. Plum-like leaves.
Pulegioides. Like Pennyroyal.
Quinquefolium. Five-leaved.
Racemosa. Full of clusters.
Repens. Creeping.
Rubra. Red.
Scariola. Papery, scaly.
Sempervirens. Evergreen.
Serotina. Late-flowering.
Serpentaria. Snake bite cure.
Serrulata. Finely serrated.
Simplicissima. Undivided.
Spicata. Bearing a spike.
Stramonium. Swelling.
Strobus. Overlapping scales; cone.
Sylvatica. Of the forest, wild.
Styraciflua. Flowering gum.
Syriaca. Of Syria.
Thalictroides. Like meadow rue.
Thapsus. Of ancient Thapsus.
Tinctoria. Of dyes.
Triphyllum. Three-leaved.
Tuberosa. Having tubers.
Umbellata. Having flowers arranged in umbels.
Villosa. Shaggy, hairy.
Viride. Green.
Vulgare. Common.

GUIDE TO THE PLANTS

In the following pages you will find descriptions and illustrations—either drawings or photographs—of 126 medicinal plants that grow in the Appalachian region. Here you will find the names of the plants, a description that will help you identify the plant, information about when the plant flowers, where to look for it, what part to harvest, and what it has been used for.

ACER SPICATUM LAM.

(ACERACEAE)

COMMON NAMES: Mountain maple, goosefoot maple, low maple, mountain maple bush, spiked maple.

DESCRIPTION:* A tall shrub or small tree that grows to 30 feet in height. Bark is drab-colored, flaky, or furrowed. Young branchlets are downy near tips. Leaves are thin, downy beneath, 3-lobed or sometimes 5-lobed, with coarse-toothed margins. Flowers are small, greenish-yellow, and generally in upright narrow spikes 3 to 5½ inches long. Fruit, which is red or yellow, matures from July through October; it is about ¾ inch long at maturity.

FLOWERING PERIOD: Late May to early October.

HABITAT: Cool woods.

HARVEST: Bark.

USES: The bark of this plant is used as an anthelmintic, tonic, and opthalmiatric. In Colonial times the bark was used for a rose-tan dye.

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*See glossary (page 21) for definitions of terms used to describe the plants and their uses.

ACER SPICATUM LAM.

(ACERACEAE)

ACHILLEA MILLEFOLIUM L.

(ASTERACEAE)

COMMON NAMES: Common yarrow, bloodwort, carpenter's grass, dog daisy, gordoloba, green arrow, milfoil, nosebleed, old man's pepper, sanguinary, soldier's woundwort, thousand-leaf, thousand-leaved clover, thousand-seal, yarrow.

DESCRIPTION: A perennial that grows to 1 to 3 feet in height. Foliage is finely cut. Leaves are aromatic, and have simple stems without stalks. Flowers are flattish and mostly white, passing to shades of deep rose-purple, clustered densely and flatly on top.

FLOWERING PERIOD: April to October.

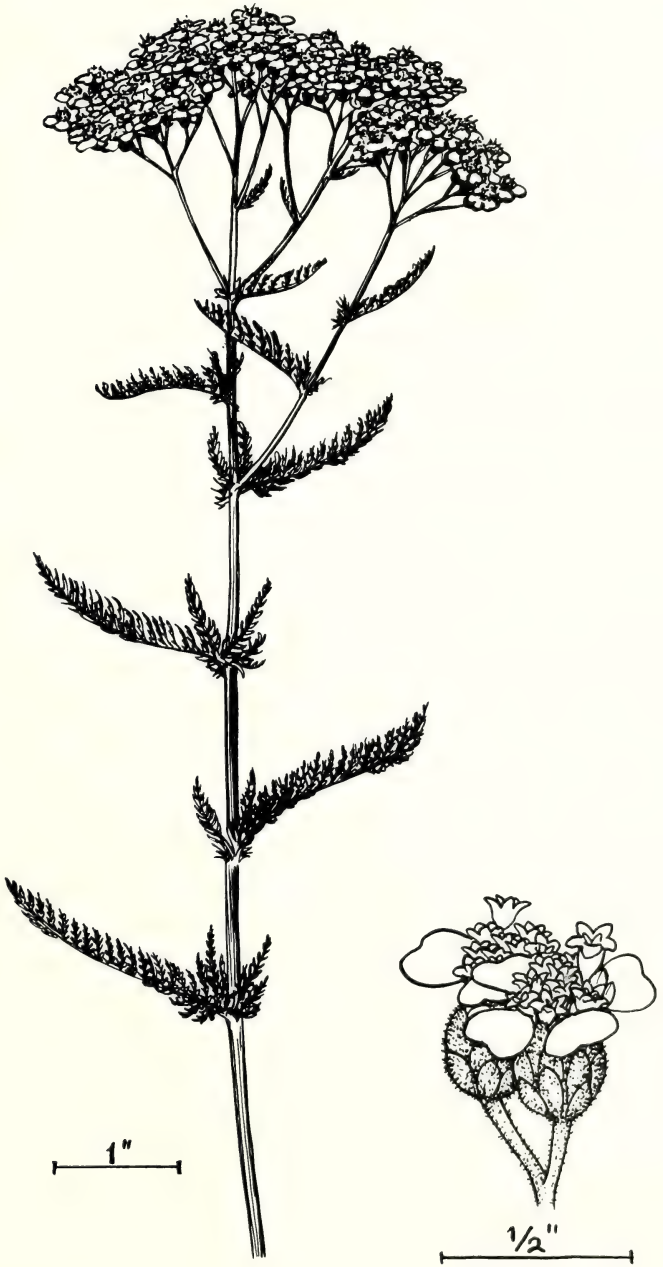
HABITAT: Abundant in pastures, old fields, roadsides, and waste places.

HARVEST: Herb and leaves in August when in flower.

USES: The herb is an aromatic with diaphoretic and emmenagogue activity; it has been used as a vulnerary.

ACHILLEA MILLEFOLIUM L.

(ASTERACEAE)



ACORUS CALAMUS L.

(ARACEAE)

COMMON NAMES: Sweet flag, beewort, bitter pepper root, calamus, drug sweetflag, flagroot, Myrtle flag, pine root, reed acorus, sweet cane, sweet cinnamon, sweet flagroot, sweet grass, sweet Myrtle, sweetroot, sweet rush, sweet sedge, sweet segg.

DESCRIPTION: A perennial. Leaves are long, narrow, and sharp-edged, and have a distinct fragrance. Flower stalk, which is 2 or 3 inches long and club-like, appears halfway up the leaf. Stalk is covered with tiny crowded greenish-yellow flowers. Plant has creeping rhizome.

FLOWERING PERIOD: May to July.

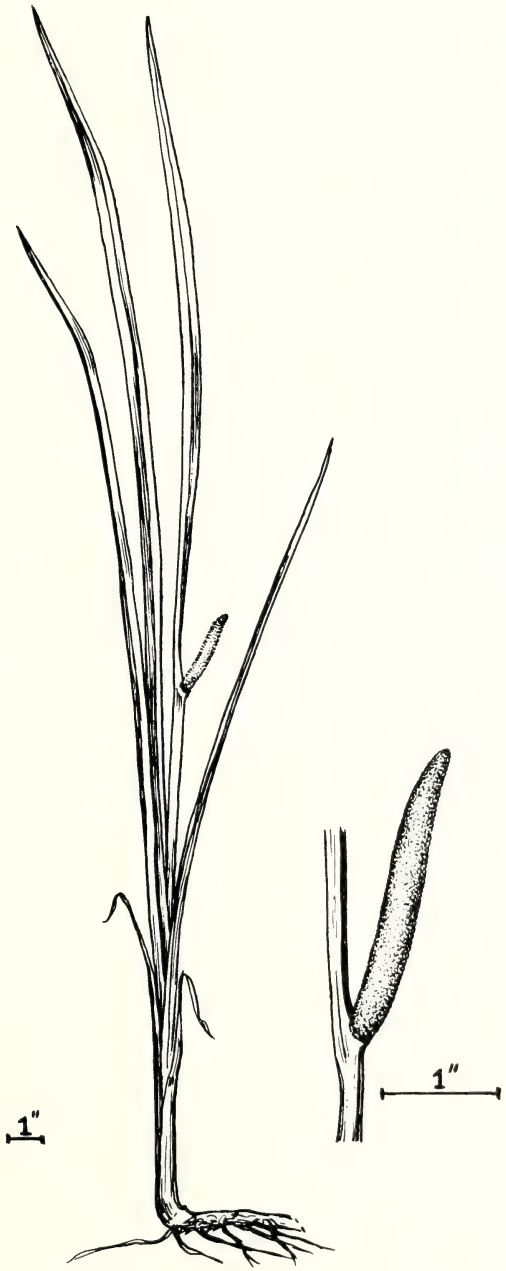
HABITAT: Swamps and edges of streams, marshes, and pond margins.

HARVEST: Rhizomes in early spring, or root in August.

USES: Plant has many uses, ranging from a flavoring agent and insecticide to tonic. In Appalachia, the root is chewed to clear the throat and to cure stomach gas; and the powdered or ground plant is used in sachets.

ACORUS CALAMUS L.

(ARACEAE)



ADIANTUM CAPILLUS-VENERIS L.

(POLYPODIACEAE)

COMMON NAMES: Southern maidenhair, black maiden's hair fern, lady's hair, maidenhair, venus' hair fern.

DESCRIPTION: A perennial fern with fronds, or stems of small leaflets, arranged alternately along a continuous stem. The pale green leaflets are fan-shaped with blunt lobes on outer curved edge. Stems are deep red-brown to shiny black. Rhizomes are creeping.

FLOWERING PERIOD: Non-flowering plant.

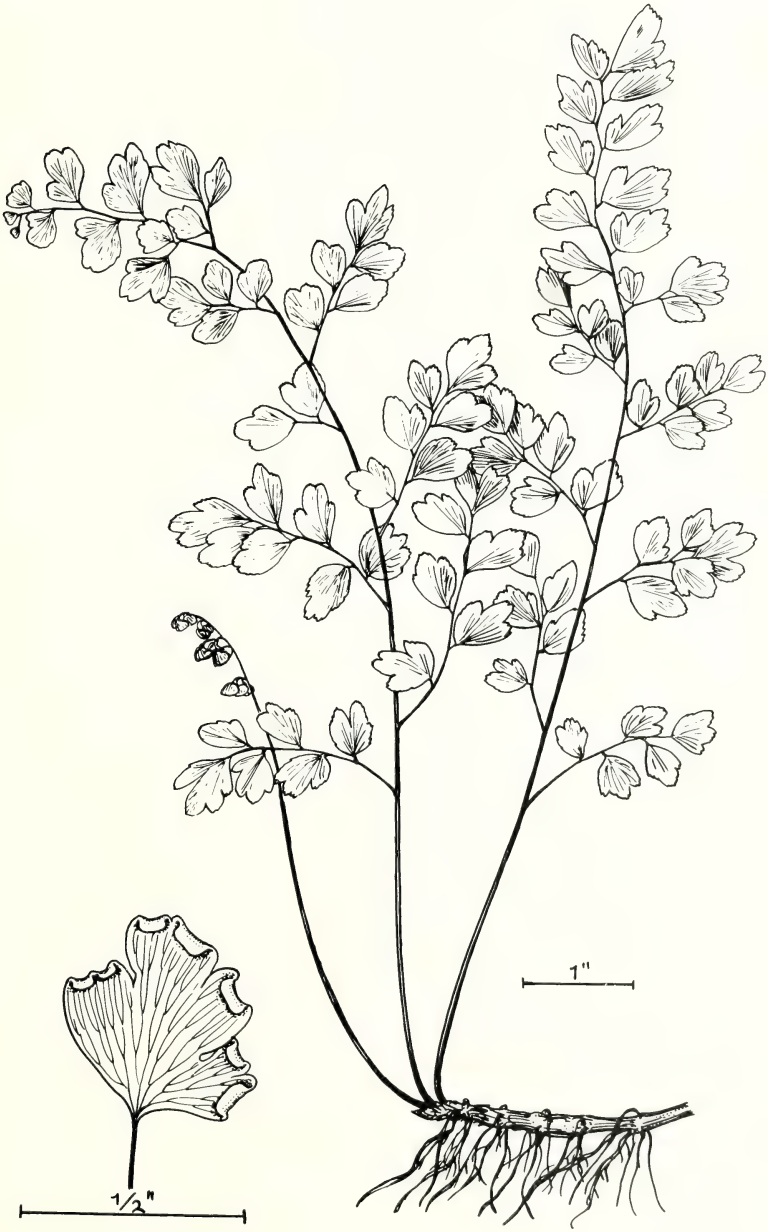
HABITAT: Moist, shaded, and limy rocks or steep banks; humus-rich woods.

HARVEST: Roots and leaves.

USES: According to existing sources, this plant has been used for an expectorant, tonic, and astringent. In Europe a tea of the herb is used to treat coughs, catarrh, and respiratory infections as well as menstrual discomfort.

ADIANTUM CAPILLUS-VENERIS L.

(POLYPODIACEAE)



ADIANTUM PEDATUM L.

(POLYPODIACEAE)

COMMON NAMES: American maidenhair, hair fern, maidenhair, maidenhair fern, rock fern, sweet fern.

DESCRIPTION: A perennial fern with fronds, or stems of small leaflets arranged alternately along a continuous stem. The pale green leaflets are fan-shaped with blunt lobes on outer curved edge. Stems are deep red-brown to shiny black. Rhizomes are creeping.

FLOWERING PERIOD: Non-flowering plant.

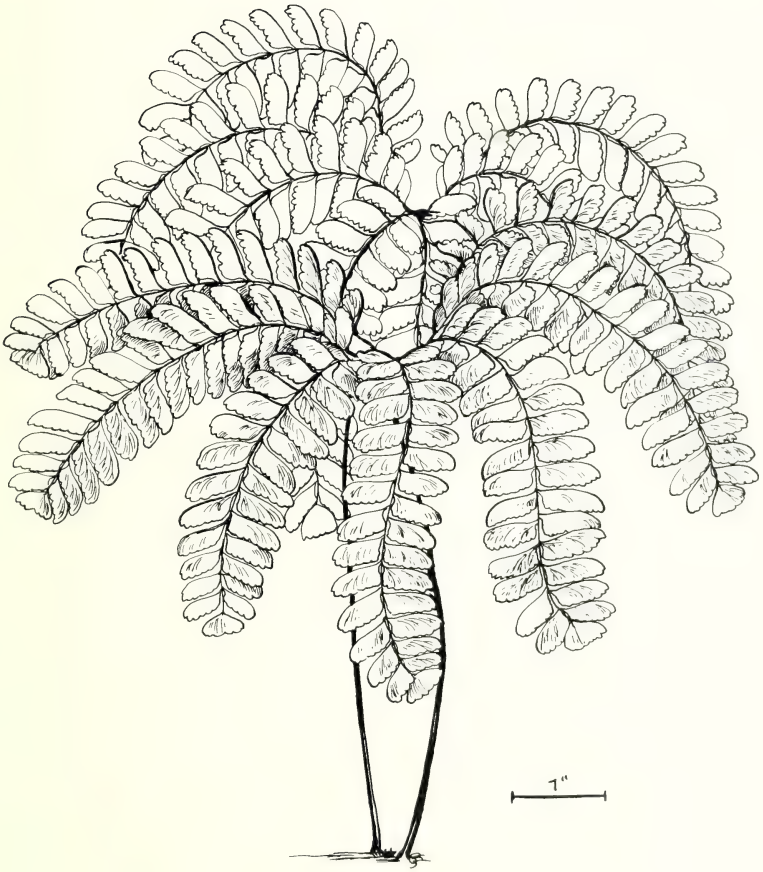
HABITAT: Moist, shaded, and limy rocks or steep banks humus-rich woods.

HARVEST: Leaves.

USES: This herb is used as a refrigerant, expectorant and tonic. A tea of this herb is used to treat coughs nasal congestion or catarrh, and hoarseness.

ADIANTUM PEDATUM L.

(POLYPODIACEAE)



AESCULUS HIPPOCASTANUM L.

(HIPPOCASTANACEAE)

COMMON NAMES: Common horsechestnut, buckeye tree, horsechestnut.

DESCRIPTION: A large tree that grows to 100 feet in height. Buds are large and sticky, nearly black. Leaves have 5 to 7 pointed leaflets 4 to 8 inches long and broader at top than at base. Flowers have large spreading white petals with red markings at base; the flowers occur in showy clusters up to 1 foot long. The fruit is round and prickly and contains a round shiny brown nut 2 inches long.

FLOWERING PERIOD: April to May.

HABITAT: Cultivated areas and some wooded areas.

HARVEST: Bark and fruit in the fall.

USES: The bark is reported to have value as a tonic an febrifuge. Traditionally, people of Appalachia have carried nut to prevent rheumatism. In Europe, an alcohol extract the nut was used to treat hemorrhoids and is considered vasa-constrictor.

AESCULUS HIPPOCASTANUM L.

(HIPPOCASTANACEAE)

ALETRIS FARINOSA L.

(LILIACEAE)

COMMON NAMES: Whitetube stargrass, ague grass, ague horn, agueroot, aletris root, aloe, aloeroot, backache root, blazing star, colicroot, crow corn, devil's bit, false unicorn root, huskwood, huskwort, mealy starwort, rheumatism root, stargrass, starwort, true unicorn root, unicorn's horns, unicorn plant, unicorn root, white colicroot.

DESCRIPTION: A perennial with wide, grass-like leaves spreading in a flat rosette around the base of a spike-like stem. White to yellow tubular flowers are arranged along the stem. Flowers have 6 lobes. Plant has a short thick root or rhizome.

FLOWERING PERIOD: May to July.

HABITAT: Moist locations in woods and meadows.

HARVEST: Rhizomes and roots in fall.

USES: The rhizomes and roots are reported to have therapeutic use as a diuretic tonic and sedative. The plant is known as colicroot because it has been used to treat colic, and ague-root because of its value in treating rheumatism, often called ague in Colonial times. In Appalachia a mixture of roots and brandy or whisky is drunk as a treatment for rheumatism.

ALETRIS FARINOSA L.

(LILIACEAE)

ALNUS SERRULATA (AIT.) WILLD.

(CORYLACEAE)

COMMON NAMES: Hazel alder, alder, American alder, black alder, candle alder, common alder, green alder, notch-leaved alder, red alder, smooth alder, speckled alder, swamp alder, tag alder.

DESCRIPTION: A shrub or small tree 4 to 25 feet in height with smooth, brownish-gray bark, which is strongly aromatic. The finely sawtoothed leaves are somewhat leathery, 2 to 4½ inches long, oval in shape, and broadest at the middle. Male flowers are borne in drooping catkins, female flowers in small, erect, oval cone-like catkins that turn hard and woody and remain on the shrub throughout winter.

FLOWERING PERIOD: February to May.

HABITAT: Swamps, wet woods, stream margins, and moist areas.

HARVEST: Bark of stems in early spring or late fall.

USES: The bark has been used as an alterative and the powdered drug as an opthalmiatric. In Appalachia, the chewed bark is used to treat wounds and ulcers. The bark has also been used for brown dye.

ALNUS SERRULATA (AIT.) WILLD.

(CORYLACEAE)

AMARANTHUS HYBRIDUS L.

(AMARANTHACEAE)

COMMON NAMES: Smooth pigweed, amaranth, careless, green amaranth, green opened amaranth, hybrid amaranthus, love lies bleeding, pigweed, prince's feather, red cockscomb, slender pigweed, slim amaranth, spleen amaranth, wild beet.

DESCRIPTION: An annual 1 to 6 feet in height, erect, branched above. Leaves are alternate, petioled, 3 to 6 inches long, dull green, rough, hairy, ovate or rhombic, with wavy margins. Flowers are small, with greenish or red terminal panicles. Taproot is long, fleshy, red or pink.

FLOWERING PERIOD: June to October.

HABITAT: Waste places, cultivated fields, and barn yards.

HARVEST: Leaves and herb.

USES: Because of its astringent quality, this plant has been used in treating dysentery, ulcers, and hemmorrhage of the bowel.

AMARANTHUS HYBRIDUS L.

(AMARANTHACEAE)

ANGELICA ATROPURPUREA L.

(UMBELLIFERAE)

COMMON NAMES: Purplestem angelica, alexanders, American angelica, angelica, archangel, Aunt Jerichos, bellyache root, common angelica, dead nettle, great angelica, high angelica, masterwort, masterwort aromatic.

DESCRIPTION: A shrub that grows to 7 feet in height. Stem is purplish. Three saw-toothed leaves occur at the tip of each leaf-stem. Leaves are alternate and compound; leaflets are 3-parted with serrate margins. White or greenish flowers occur in terminal clusters at the end of stalk. Stalks and clusters are arranged in a semicircle or umbel.

FLOWERING PERIOD: June to August.

HABITAT: Mostly cultivated in gardens; in rich low grounds, and near streams and swamps.

HARVEST: Root in fall.

USES: The drug contains volatile oil that is used as a flavoring agent and in treating colic and flatulence. Some sources list it as an expectorant. A confection prepared by sugaring the boiled stems is considered a gourmet favorite. In Europe a root infusion is used to treat dyspepsia and stomach diseases and is considered diuretic and expectorant.

ANGELICA ATROPURPUREA L.

(UMBELLIFERAE)

APLECTRUM HYEMALE (MUHL.) TORR.

(ORCHIDACEAE)

COMMON NAMES: Puttyroot, Adam-and-Eve-root.

DESCRIPTION: A perennial orchid that grows from a series of bulb-like roots attached by narrower roots. The plant has a single, broad, elliptical pointed leaf at the base. Flower spike, which arises from the root, has small leaflike structures enclosing the stem. Flower is purplish toward its base and brown toward its summit, with white lip.

FLOWERING PERIOD: May to June.

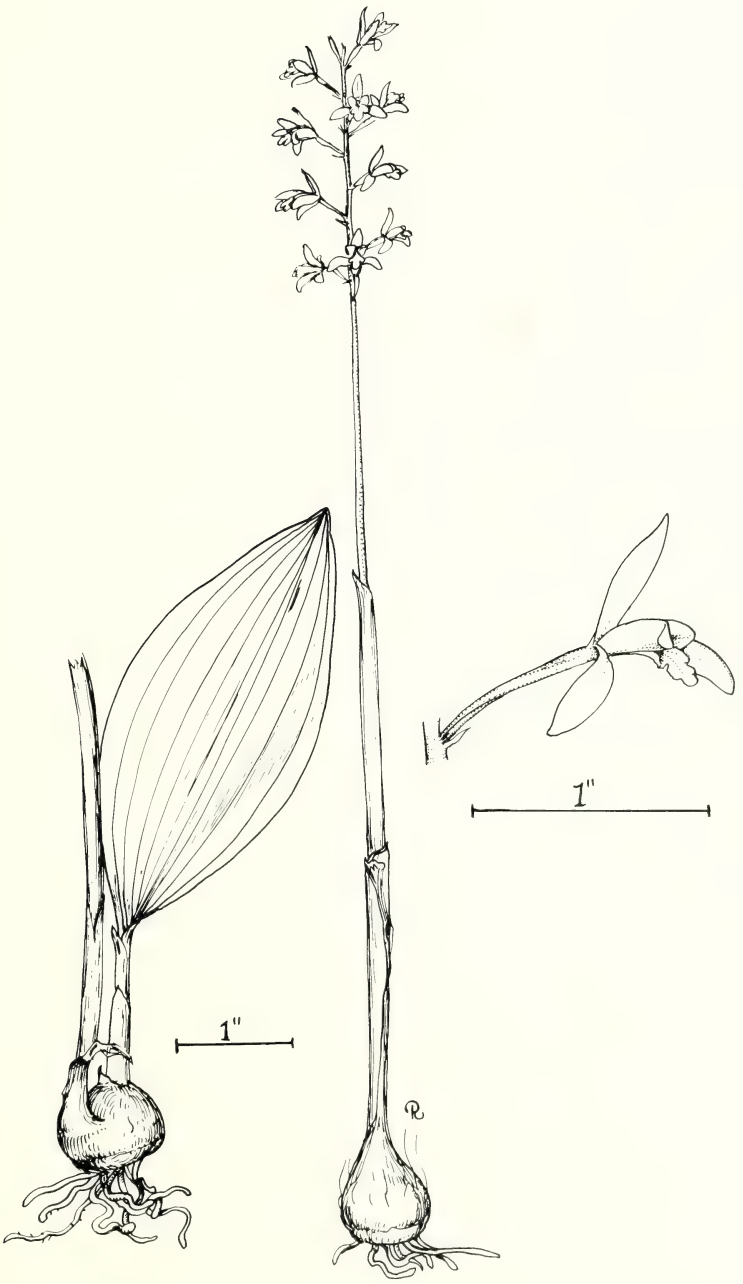
HABITAT: Moist shaded woods and in set soil of flood plains.

HARVEST: Roots in fall.

USES: Plant is reputed to have value in treating bronchial ailments.

APLECTRUM HYEMALE (MUHL.) TORR.

(ORCHIDACEAE)



APOCYNUM ANDROSAEMIFOLIUM L.

(APOCYNACEAE)

COMMON NAMES: Spreading dogbane, American ipecac, bitter dogbane, bitter-root, black Indian hemp, catch fly, colicroot, common dog's-bane, dogbane, fly trap, honey bloom, Indian hemp, milk ipecac, milkweed, rheumatism wood, wandering milkweed, western wallflower, wild ipecac.

DESCRIPTION: A perennial that grows to 3 to 6 feet in height, and is widely spread from horizontal rootstock. Leaves opposite, nearly sessile. Flowers large, oval, and whitish. The pods are double, 4 to 6 inches long, and slender. The plant produces a milky juice.

FLOWERING PERIOD: June to August.

HABITAT: Open woods, roadside banks, meadows, thickets, and stream banks.

HARVEST: Roots and rhizomes in late fall.

USES: This plant, which is extremely poisonous, is a cardioactive drug. It has been used also as a tonic, diuretic, and purgative.

APOCYNUM ANDROSAEMIFOLIUM L.

(APOCYNACEAE)

APOCYNUM CANNABINUM L.

(APOCYNACEAE)

COMMON NAMES: Hemp dogbane, American hemp, amyroot, bitter-root, Bowman's root, Canadian hemp, choctaw root, glabrous hemp, Indian hemp, Indian physic, milkweed, rheumatism weed, silkweed, wild cotton.

DESCRIPTION: This perennial is generally 3 to 6 feet in height, and is unbranched except near the top. It has large elliptical, opposite leaves with short stalks. It produces whitish-green flowers borne on terminal clusters, and a milky juice. The pods are double, 4 to 6 inches long, and slender. The seeds are tufted.

FLOWERING PERIOD: May to July.

HABITAT: Dry waste places and forest borders.

HARVEST: Roots and rhizomes in late fall.

USES: This plant is a cardiotonic drug that is extremely poisonous. It has been used as a diuretic, diaphoretic, expectorant, and emetic. Because of its use by American Indians in treating dropsy, it has been called dropsy weed. Indians also used the tough fibrous bark to make fishing nets, and some western Indians chewed dried bits of the latex. The plant exhibits cytotoxicity but no antitumor activity.

APOCYNUM CANNABINUM L.

(APOCYNACEAE)

ARALIA NUDICAULIS L.

(ARALIACEAE)

COMMON NAMES: Wild sarsaparilla, American sarsaparilla, American spikenard, false sarsaparilla, rabbit's foot, sarsaparil, sarsaparilla, sarsaparilla root, shotbush, small spikenard, small spikeweed, spignet, spikenard, sweetroot, Virginian sarsaparilla, wild licorice.

DESCRIPTION: A short-stemmed perennial that grows to 1 foot in height. Flowers are small and greenish-yellow in 3 clusters of 12 to 30 flowers on the stalk. Plant produces purplish-black berry-like fruits.

FLOWERING PERIOD: May to July.

HABITAT: Deep mountain woodlands.

HARVEST: Roots in late summer and fall.

USES: The roots and rhizomes have been used as a diuretic, diaphoretic, and cough remedy.

ARALIA NUDICAULIS L.

(ARALIACEAE)

ARALIA RACEMOSA L.

(ARALIACEAE)

COMMON NAMES: American spikenard, American sarsaparilla, Indian root, life-of-man, old man's root, petty morrel, pigeon weed, spignet, spikenard.

DESCRIPTION: A perennial 1 to 9 feet in height, with a single leaf stalk. Leaf is divided into 3 parts, each with five leaflets. Flowering stalk is elongated, with small greenish-yellow flowers in clusters. Produces a blackish or purplish berry. Root is larger than the root on *nudicaulis*.

FLOWERING PERIOD: June to August.

HABITAT: Bluffs, deep woods, and river banks.

HARVEST: Roots in summer and fall.

USES: Roots and rhizomes have been used to treat rheumatism, syphilis, coughs, and shortness of breath. In Appalachia, a tea made of roots is used for backache.

ARALIA RACEMOSA L.

(ARALIACEAE)

ARCTIUM LAPPA L.

(ASTERACEAE)

COMMON NAMES: Great burdock, beggar's buttons, burdock, clotbur, lappa.

DESCRIPTION: A biennial or perennial 3 to 8 feet in height, with many flowered heads. Leaves are large, broad, and rounded—like those on rhubarb. The tube-shaped flowers are pale pink, deep purple, or white. Big brown, round, bristly burrs are a common characteristic of the plant.

FLOWERING PERIOD: July to October.

HABITAT: Fields and roadsides.

HARVEST: Root of plant's first year of growth; can be harvested anytime.

USES: The United States Dispensatory no longer lists this herb as medicinally valuable, but in the past it was quite popular for treating many ailments. In Spain and France it has been used to purify the blood and to cure skin blemishes and minor wounds. In 18th Century America it was prescribed as a cure for gonorrhea and syphilis. In Appalachia, a tea of roots or seeds is used to treat rheumatism and to purify the blood.

ARCTIUM LAPPA L.

(ASTERACEAE)

ARCTIUM MINUS (HILL) BERNH.

(ASTERACEAE)

COMMON NAMES: Common burdock, burdock, clotbur, cuckoo button, smaller burdock.

DESCRIPTION: A biennial or perennial 3 to 8 feet in height, with many flowered heads. Leaves are large, broad, and rounded—like those on rhubarb. The tube-shaped flowers are pale pink, deep purple, or white. Big, brown, round, bristly burrs are a common characteristic.

FLOWERING PERIOD: June to October.

HABITAT: Fields and pastures.

HARVEST: Roots in the fall of plant's first year of growth; seeds the second year of growth.

USES: Plant is a diaphoretic, diuretic, alterative, and depurative. It is used externally in salves or as a wash for burns, skin irritations, and minor wounds.

ARCTIUM MINUS (HILL) BERNH.

(ASTERACEAE)

ARISAEMA TRIPHYLLUM (L.) SCHOTT.

(ARACEAE)

COMMON NAMES: Indian Jack-in-the-pulpit, bog onion, cuckoo plant, dragon root, dragon turnip, Indian turnip, Jack-in-the-pulpit, lords and ladies, meadow turnip, memory root, pepper turnip, priest's pintle, small Jack-in-the-pulpit, starchwort, swamp turnip, thrice-leaved arum, wake robin, wild turnip.

DESCRIPTION: A perennial that has 2 stalks of 3 leaves each, and grows another stalk topped with a green tubular pulpit, which has a hood turned down over it that protects an inside green or dark purple tube. The pulpit stalk has brilliant crimson berries in dense clusters.

FLOWERING PERIOD: April to June.

HABITAT: Rich damp woodlands and bogs.

HARVEST: Corm in summer or fall.

USES: The boiled corms of this plant were a mainstay in the diet of the American Indians. Because of the needle-like calcium oxalate crystals, the raw corm is extremely irritating and toxic. The plant has been used as an expectorant, irritant, and diaphoretic.

ARISAEMA TRIPHYLLUM (L.) SCHOTT.

(ARACEAE)

ARISTOLOCHIA SERPENTARIA L.

(ARISTOLOCHIACEAE)

COMMON NAMES: Virginia snakeroot, birthwort, Dutchmans-pipe, pelican flower, sangrel, sangrel-root, serpentaria, serpentary root, snakeroot, snakeweed, thick birthwort.

DESCRIPTION: This perennial is 1 to 2 feet in height. It has an erect stem and heart-shaped leaves that taper to a point at the tip. Brownish pipe-like flowers grow from base of the plant stem.

FLOWERING PERIOD: May to June.

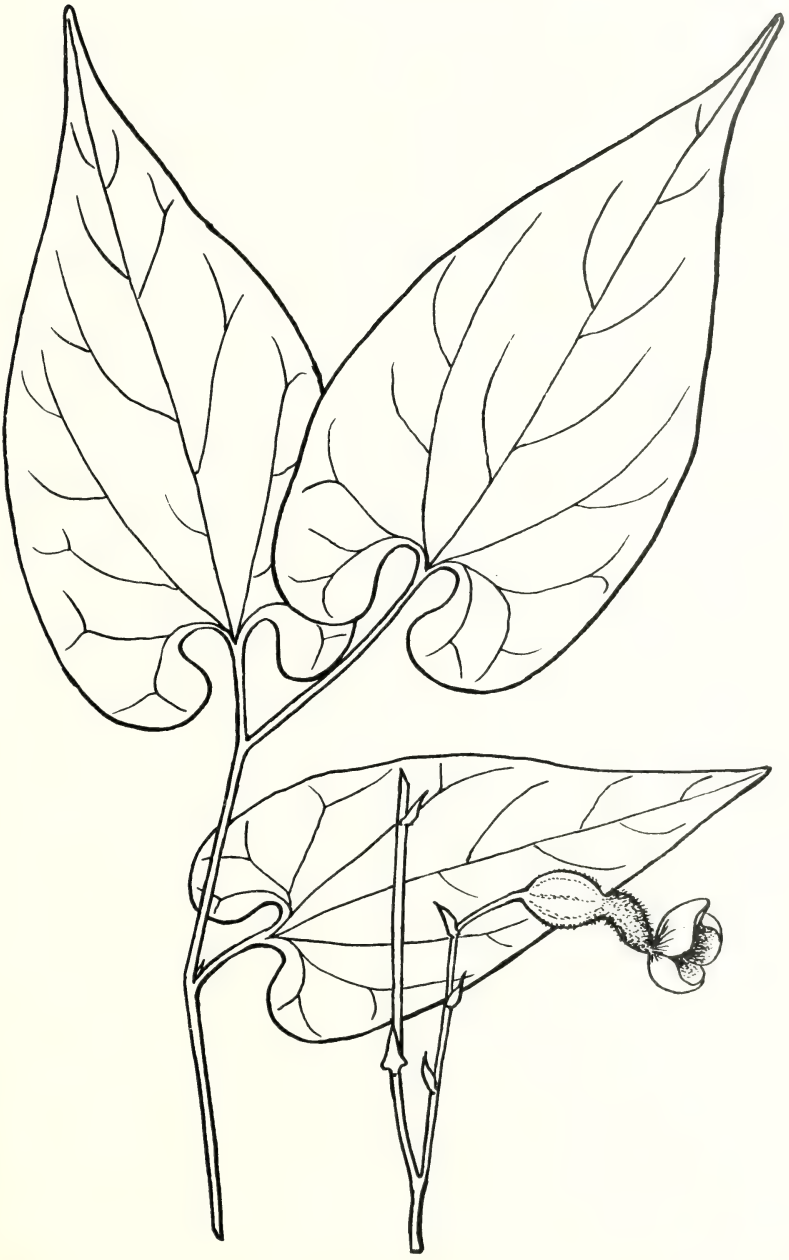
HABITAT: Forests, woodlands, and stream banks.

HARVEST: Rootstock and roots in fall.

USES: Preparations from this herb have been used as aids in dyspepsia, as antispasmodics, diaphoretics, and emmenagogues.

ARISTOLOCHIA SERPENTARIA L.

(ARISTOLOCHIACEAE)



ASARUM CANADENSE L.

(ARISTOLOCHIACEAE)

COMMON NAMES: Canada wild ginger, black snakeroot, black snakeweed, broad-leaved sarabacca, Canada snakeroot, cat-foot, colicroot, coltsfoot, coltsfoot snakeroot, false colt's foot, heart snakeroot, Indian ginger, southern snakeroot, wild ginger.

DESCRIPTION: A low-growing stemless perennial with heart-shaped soft leaves growing from a rhizome. Thick, brownish, bell-shaped flowers, purple inside, are found near the root. The flowers are often hidden under dry leaves. The stem has a spicy odor.

FLOWERING PERIOD: April to May.

HABITAT: Cool, moist, deep woods and slopes.

HARVEST: Rhizome in spring or fall, and roots anytime.

USES: The first common name of this plant, Canada wild ginger, indicates the aromatic quality of its rhizome. It was used as a flavoring agent in Colonial America in place of Jamaica ginger. The rhizome has value as an expectorant, antiseptic, and tonic. In Appalachia a root tea is used to relieve stomach gas.

ASARUM CANADENSE L.

(ARISTOLOCHIACEAE)

ASCLEPIAS SYRIACA L.

(ASCLEPIADACEAE)

COMMON NAMES: Common milkweed, common silkweed, cottonweed, milkweed, silkweed, silky swallow-wort, wild cotton.

DESCRIPTION: A perennial that generally grows to 4 to 5 feet in height. Leaves are broadly oval, opposite, or whorled, pubescent beneath, and measure 4 to 8 inches long. Dull greenish-purple flowers are clustered in a head.

FLOWERING PERIOD: June to August.

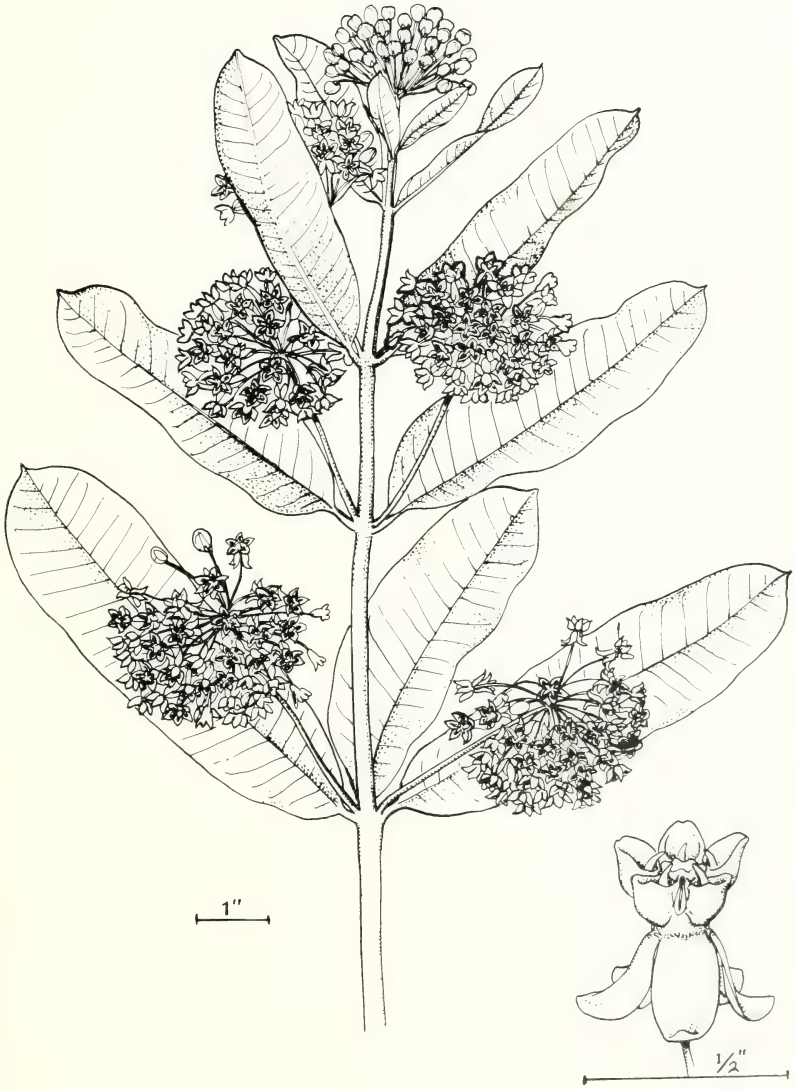
HABITAT: Thickets, meadows, fields, orchards, and along roadsides.

HARVEST: Roots in fall.

USES: Reputedly this plant is valuable as an expectorant, antirheumatic, diaphoretic, and diuretic. It is also a source of glucoside and alkaloid. In Appalachia it is used to treat warts and moles. The white juice of this plant is extremely irritating to the eyes.

ASCLEPIAS SYRIACA L.

(ASCLEPIADACEAE)



ASCLEPIAS TUBEROSA L.

(ASCLEPIADACEAE)

COMMON NAMES: Butterfly milkweed, butterfly weed, Canada root, chigger flower, fluxroot, Indian nosy, orange apocynum, orange milkweed, orangeroot, orange swallow-wort, pleurisy root, rubber root, silkweed, swallow-wort, tuberous-rooted swallow-wort, tuber root, white root, wind root, wind weed, wine tree.

DESCRIPTION: A very leafy, slightly hairy perennial that grows to 2 to 3 feet in height. Leaves are 2 to 6 inches long, narrow, alternate, and short petioled. Orange-yellow flowers are in umbels. Fruit is a pod. Seeds have white silky hairs.

FLOWERING PERIOD: May to August.

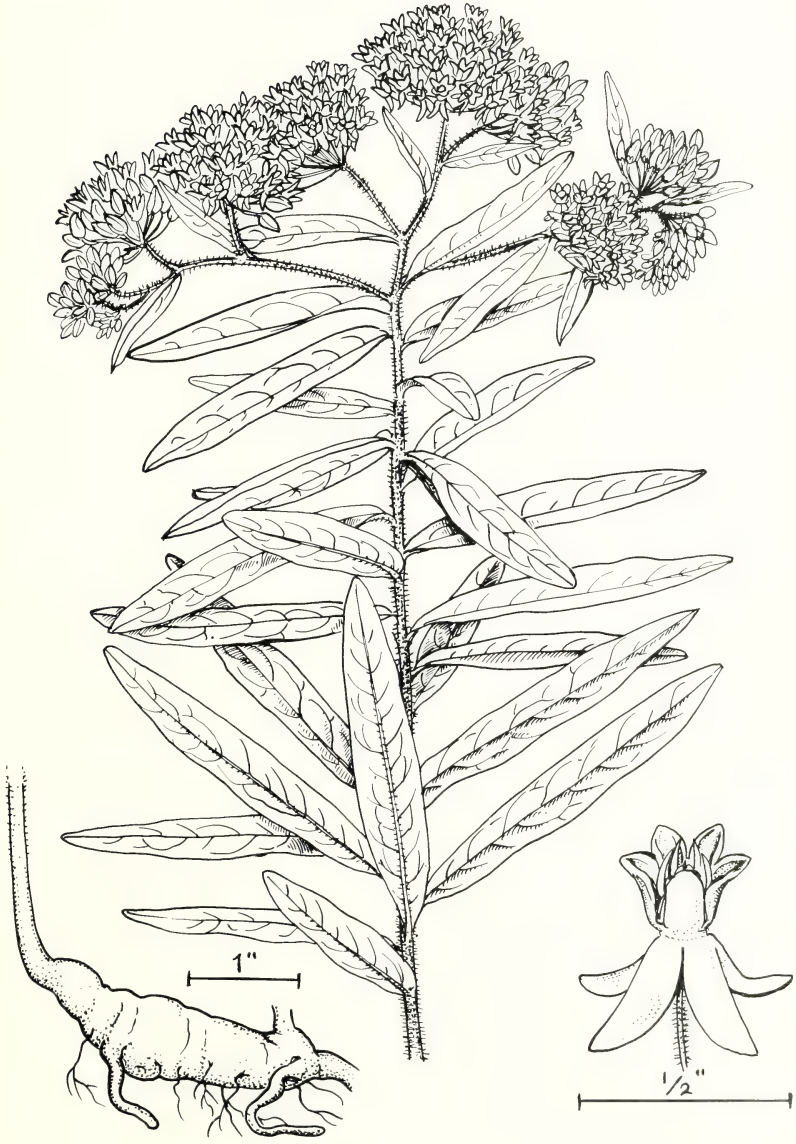
HABITAT: Sandy, dry open soils, pastures, and roadsides.

HARVEST: Roots in fall.

USES: The plant has been used as an expectorant, diaphoretic, and emetic, and to treat rheumatism. Indians of Appalachia made a tea of the leaves to induce vomiting.

ASCLEPIAS TUBEROSA L.

(ASCLEPIADACEAE)



BAPTISIA TINCTORIA (L.) R. BR.

(FABACEAE)

COMMON NAMES: Wild indigo, clover bloom, dyer's baptisia, false indigo, horsefly weed, indigo broom, indigo weed, rattlebush, rattleweed, yellow broom, yellow wild indigo.

DESCRIPTION: A perennial that grows 2 to 4 feet in height. Stem is erect, and has alternate branches that contain several whorls of 3 clover-like leaflets. Each branch has a whorl of 3 leaflets where it attaches to the stem. Leaves are nearly sessile. Yellow flowers, which are arranged at the tops of the highest branches, are ½ inch long, and form brown ½-inch cylindrical pods.

FLOWERING PERIOD: April to August.

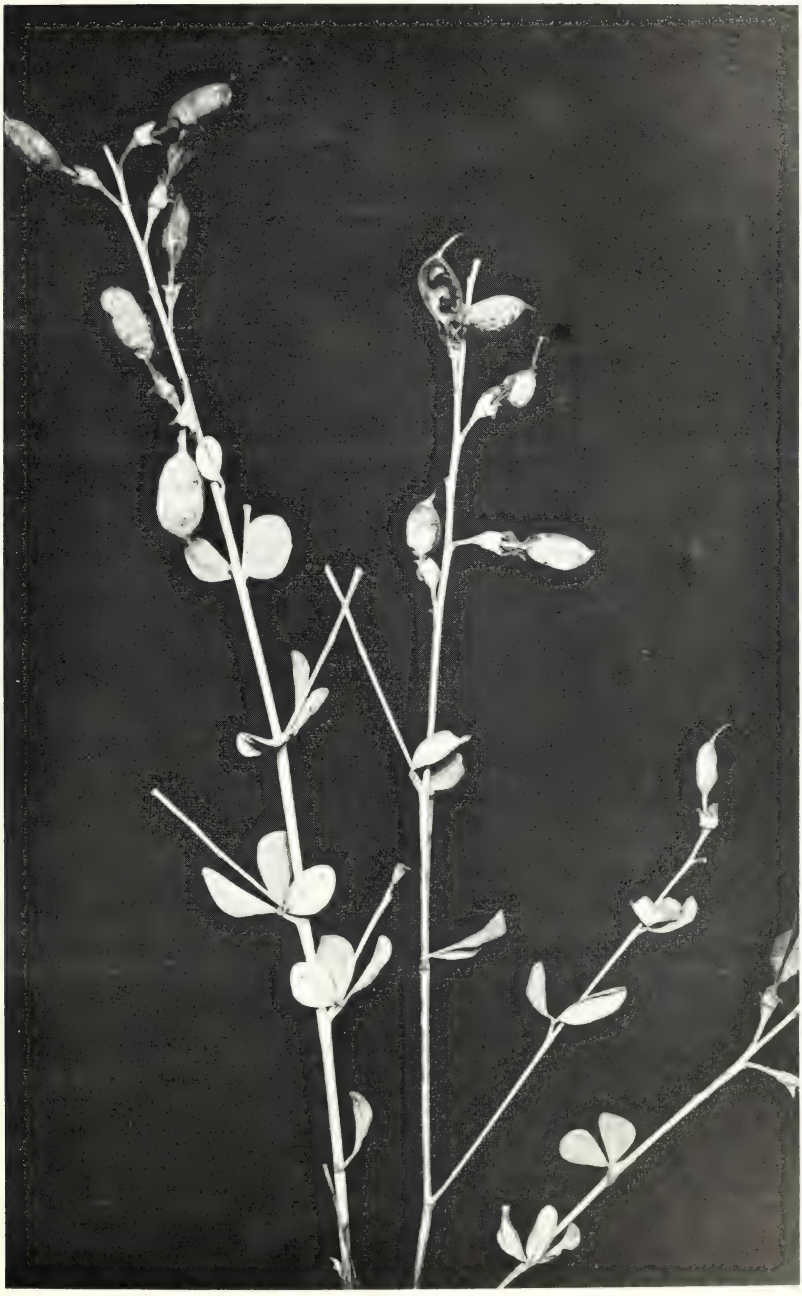
HABITAT: Mostly in dry open woods and clearings.

HARVEST: Roots in fall, herb in summer.

USES: Most authors agree that the herb has value as a febrifuge, tonic, purgative, and antiseptic.

BAPTISIA TINCTORIA (L.) R. BR.

(FABACEAE)



BERBERIS VULGARIS L.

(BERBERIDACEAE)

COMMON NAMES: European barberry, American barberry, barberry, common barberry, dragon grape, guild tree, jaundice barberry, jaundice berry, pepperidge bush, sow berry, wood sour, yellow root.

DESCRIPTION: A perennial shrub that grows to 8 feet in height. Leaves are small, ovate, grayish below; leaves on young sprouts are spiny. Yellow flowers are in racemes 1 to 2 inches long. Fruit is oblong, scarlet to purple. Inner wood is yellow. Bark is gray, having sharp spines at nodes.

FLOWERING PERIOD: May to July.

HABITAT: Pastures, thickets, and fence rows.

HARVEST: Root and stem, root bark, and fruit in fall.

USES: The fruit is rich in Vitamin C and has been used in treating certain vitamin deficiencies. The root bark, which is astringent, has been used to treat diarrhea, dysentery, and jaundice. In Europe, a root infusion is used to treat chronic dyspepsia.

BERBERIS VULGARIS L.

(BERBERIDACEAE)

BETULA LENTA L.

(CORYLACEAE)

COMMON NAMES: Sweet birch, black birch, cherry birch, mountain mahogany, river birch, spice birch.

DESCRIPTION: A tree that grows to 80 feet in height. Bark is dark reddish-brown, close-fissured into thick plates on old trunks. Leaves are 2½ to 5 inches long and 1½ to 3 inches wide (widest near the base); they are also finely toothed on the edges, and rounded at the base. Bark and leaves are sweet and aromatic. Tree bears both male and female flowers in catkins or caterpillar-like spikes ½ inch long.

FLOWERING PERIOD: April to mid-May.

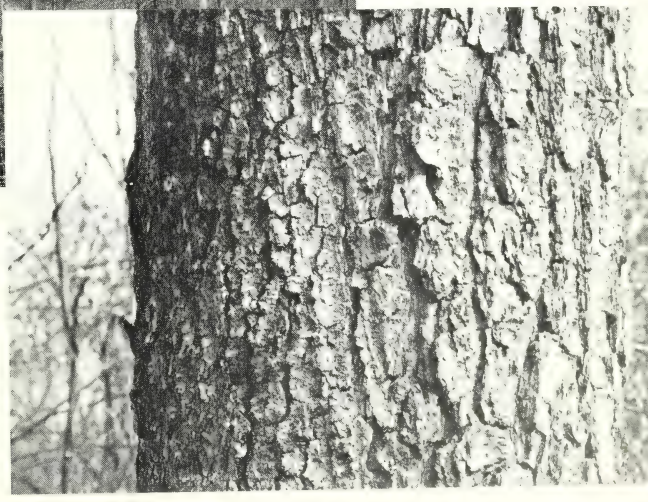
HABITAT: Rich woods and moist, well-drained to shallow soils.

HARVEST: Bark and twigs from May to late September.

USES: The bark of this plant contains small quantities of methyl salicylate and has a pleasant aromatic flavor similar to wintergreen. The bark has been used as an astringent, antiseptic, antipyretic, and antirheumatic. The sap may be made into vinegar. Birch beer is also made from this tree.

BETULA LENTA L.

(CORYLACEAE)



CAULOPHYLLUM THALICTROIDES (L.) MICHX.

(BERBERIDACEAE)

COMMON NAMES: Blue cohosh, blueberry cohosh, blueberry root, blue ginseng, papoose root, squaw root, yellow ginseng.

DESCRIPTION: A perennial that grows to 3 feet in height. It has an almost sessile leaf at top, and leaflets are either 2- or 3-lobed. In spring, plant sends up a small, elongated axis of yellowish-green flowers. Rootstock is knotty and matted.

FLOWERING PERIOD: April to early June.

HABITAT: Richly wooded mountains and hardwood glades.

HARVEST: Rhizomes and roots in the fall.

USES: This herb has been called papoose root or squaw root because of its use by American Indians to facilitate childbirth. The rhizome has been used to treat chronic rheumatism, bronchitis, and colic.

CAULOPHYLLUM THALICTROIDES (L.) MICHX.

(BERBERIDACEAE)

CEANOTHUS AMERICANUS L.

(RHAMNACEAE)

COMMON NAMES: Jersey tea ceanothus, New Jersey tea, red root, wild snowball.

DESCRIPTION: A shrub that grows to 2 to 3 feet in height. It has straggling, downy, alternate, ovate, finely-toothed leaves that are pale green below and dark green above. The plant produces white flowers on long stalks at upper axils.

FLOWERING PERIOD: May to September.

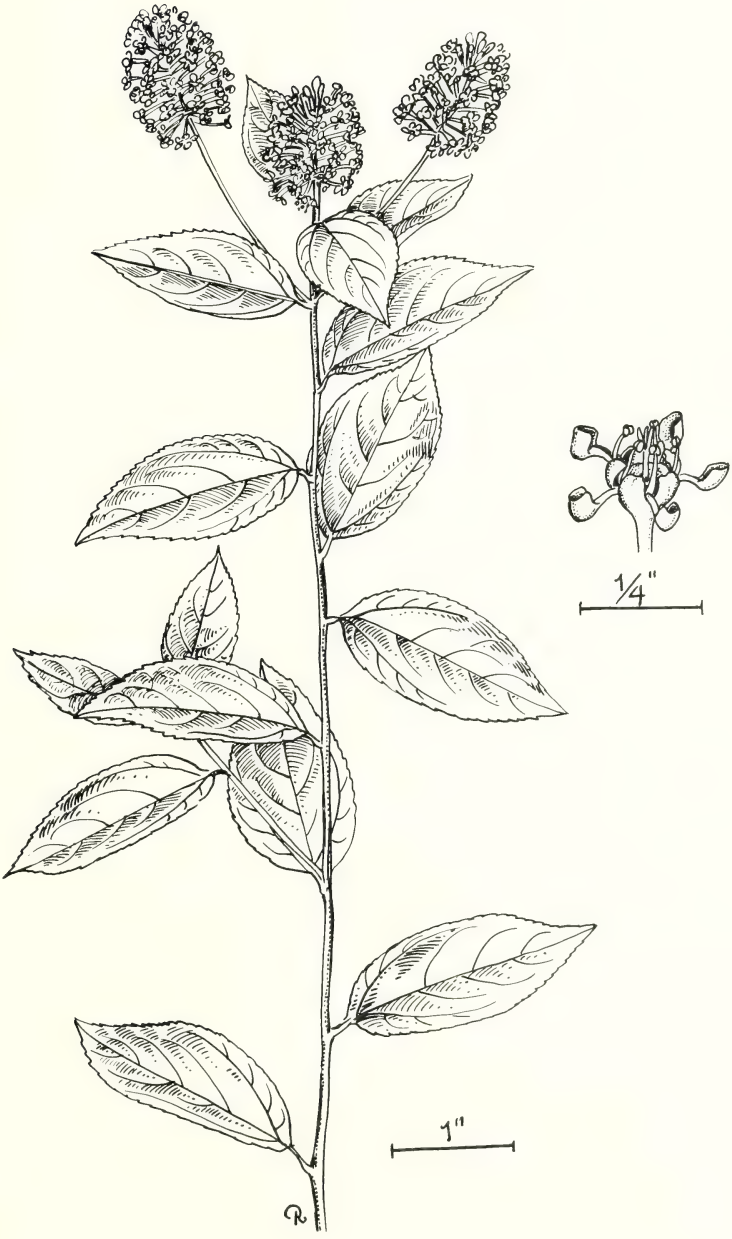
HABITAT: Upland deciduous forests, roadsides, dry open woods, and rocky banks.

HARVEST: Bark of root, root, and leaves.

USES: The root is reportedly used as an astringent, stimulant, antispasmodic, expectorant, and sedative. According to one authority, the root is also used to treat respiratory ailments. In Europe it has been used to reduce high blood pressure and to treat enlarged spleen. The leaves are used for a tea.

CEANOTHUS AMERICANUS L.

(RHAMNACEAE)



CHAMAELIRIUM LUTEUM (L.) GRAY

(LILIACEAE)

COMMON NAMES: Fairywand, blazing star, devil's bit, false unicorn, grub root, helonias, rattlesnake root, star root, starwort.

DESCRIPTION: A perennial that grows to 4 feet in height. Plant produces a rosette of basal leaves from which a spike rises. A few narrowly linear leaves may be found on the spike. Male and female flowers are on different plants. The male flowers are white and, when dried, yellowish; the female flowers are greenish.

FLOWERING PERIOD: April to July.

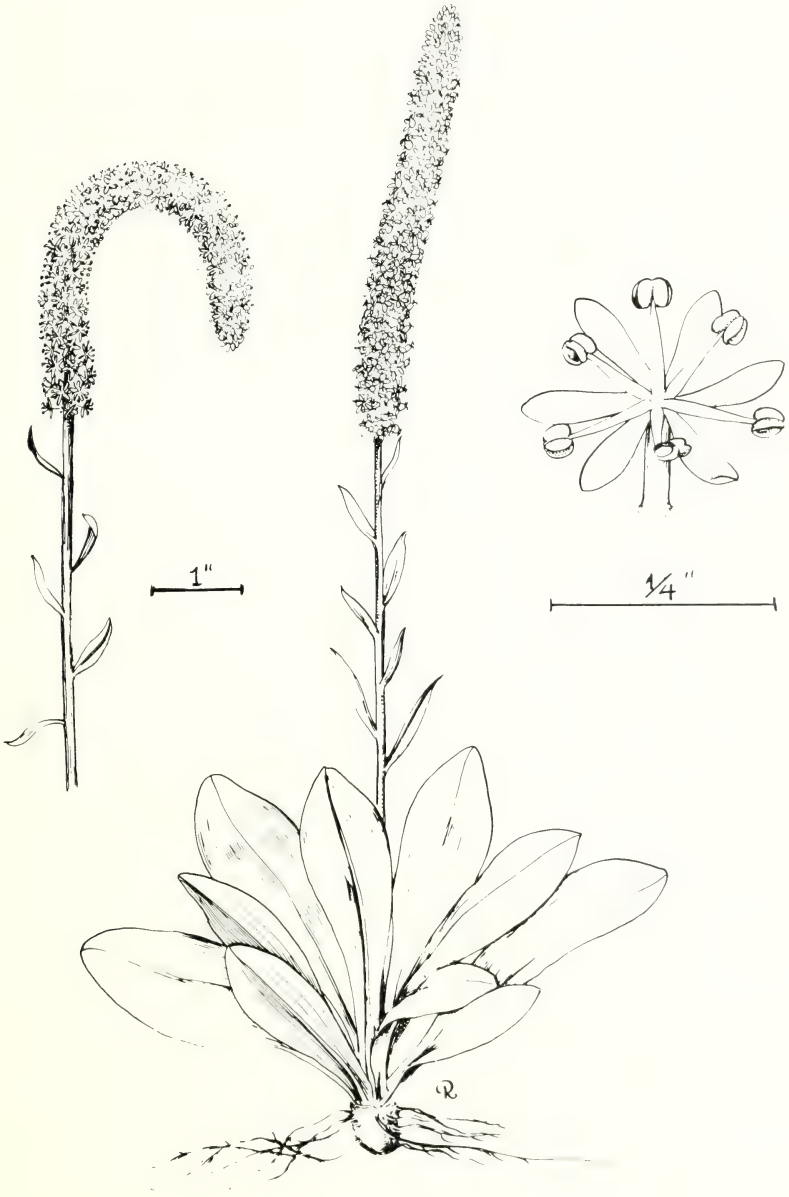
HABITAT: Bogs and wet places in woodlands, meadows, and thickets.

HARVEST: Rootstock in fall.

USES: This herb has been used as a diuretic, diaphoretic, anthelmintic, purgative, and tonic.

CHAMAELIRIUM LUTEUM (L.) GRAY

(LILIACEAE)



CHELONE GLABRA L.

(SCROPHULARIACEAE)

COMMON NAMES: White turtlehead, balmony, bitter herb, fishmouth, salt-rheum weed, shellflower, smooth snakehead, snakehead, snakemouth, true snakehead, turtle bloom, turtlehead.

DESCRIPTION: A perennial that grows to 3 feet in height. Leaves are opposite, narrow, and 2 to 6½ inches long. Flowers are rose-white and about 1 inch long. A pale, beard-like structure is found within the turtlehead flower tube.

FLOWERING PERIOD: August to October.

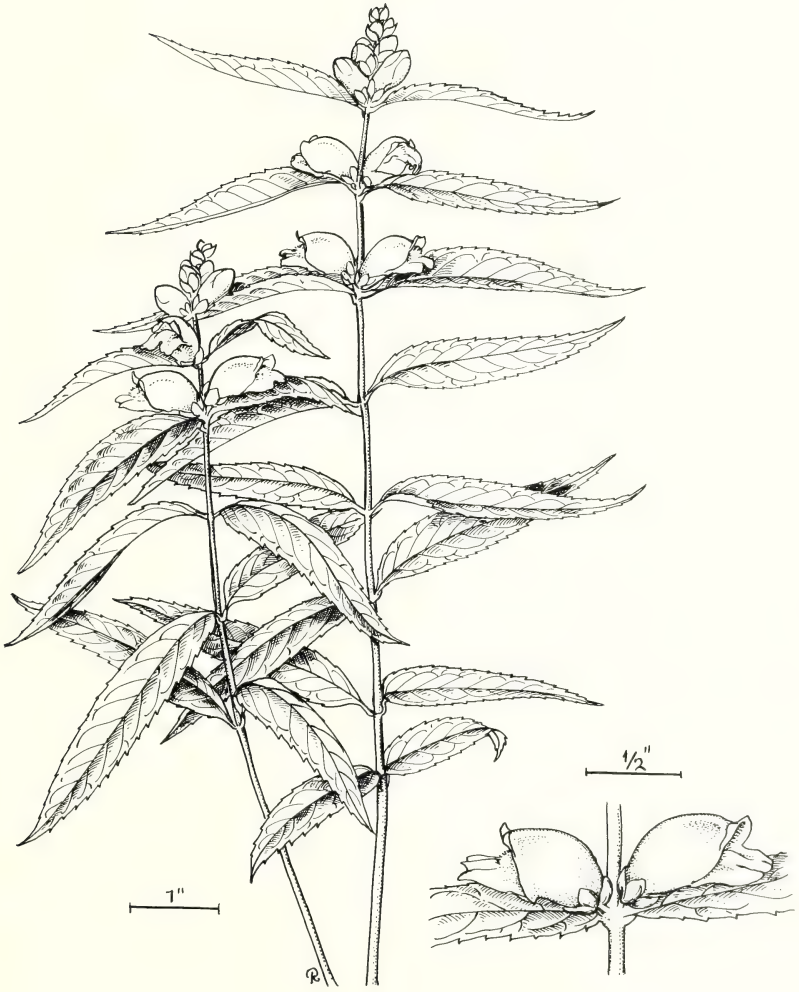
HABITAT: Low grounds, woodland, margins of streams, and wet thickets.

HARVEST: Herb at flowering time; leaves in spring.

USES: The leaves have been used for reducing inflammation, and as an anthelmintic and tonic.

CHELONE GLABRA L.

(SCROPHULARIACEAE)



CHENOPODIUM AMBROSIOIDES L.

(CHENOPODIACEAE)

COMMON NAMES: Mexican tea, ambrosia, ambrosia-like chenopodium, American wormseed, goose foot, Jerusalem oak seed, Jerusalem tea, jesuit tea, Spanish tea, stickweed, stinking weed, wild wormseed, wormseed, wormseed goosefoot.

DESCRIPTION: An annual that grows to 3½ feet in height. Branches sprout profusely from the base. Leaves are alternate, ovate to lanceolate in shape, and about 5 inches long. Small, greenish flowers grow along small, leafless spikes in the axils of the leaves.

FLOWERING PERIOD: July to October.

HABITAT: Waste places, cultivated ground, abandoned fields.

HARVEST: Fruit in summer, entire plant or seed from August to November.

USES: Primary use is in the manufacturing of chenopodium oil, which is used to treat intestinal worms, both in humans and animals. The pollen is allergenic. In Mexico it is cooked and eaten as a vermifuge, and in Europe it is used as an infusion. In New Mexico, Spanish speaking people use a tea made of the leaves to encourage milk flow and to relieve post-delivery pains.

CHENOPODIUM AMBROSIOIDES L.

(CHENOPODIACEAE)

CHIMAPHILA MACULATA (L.) PURSH.

(PYROLACEAE)

COMMON NAMES: Spotted wintergreen, dragon's tongue, pepsissewa, ratsbane, rheumatism root, spotted pipsissewa, wild arsenic, wintergreen.

DESCRIPTION: An evergreen perennial that grows to 10 inches in height. Leaves are dark green, blunt-toothed, and wedge-shaped. Flowers are about ½ inch in size, flesh-colored, with violet pollen sacs.

FLOWERING PERIOD: May to June.

HABITAT:Coniferous and hardwood forests.

HARVEST: Leaves.

USES: According to at least two authorities, this plant is used as a diuretic, tonic, and astringent. It is used also, according to other authorities, to treat skin eruptions, certain types of cancer, acute rheumatism, and syphilis. Still other uses are as an aromatic and alterative.

CHIMAPHILA MACULATA (L.) PURSH.

(PYROLACEAE)

CHIMAPHILA UMBELLATA (L.) NUTT.

(PYROLACEAE)

COMMON NAMES: Common pipsissewa, bitter wintergreen, fragrant wintergreen, ground holly, king's cure, love-in-winter, noble pine, pine tulip, pipsissewa, prince's pine, princess pine, pyrole, rheumatism weed, waxflower, wintergreen.

DESCRIPTION: An evergreen perennial that grows to 10 inches in height. Leaves are dark green, blunt-toothed, and wedge-shaped. Flowers are about ½ inch in size, flesh-colored, with violet pollen sacs.

FLOWERING PERIOD: May to June.

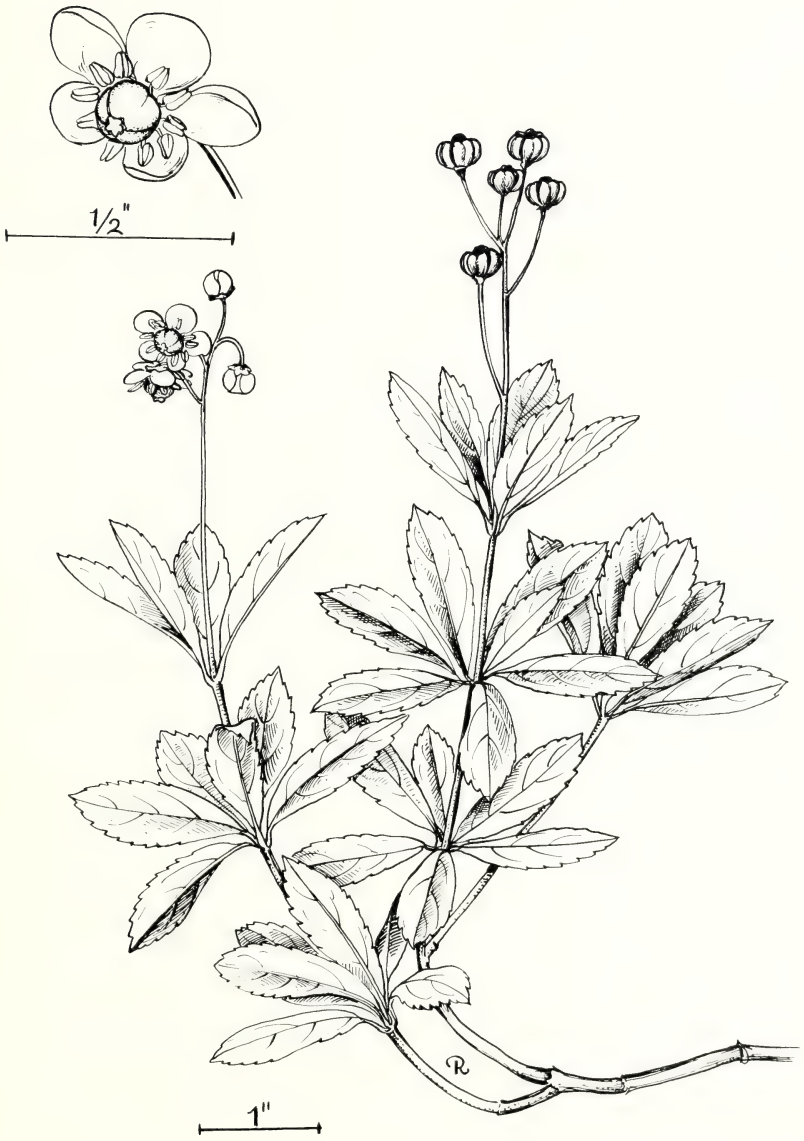
HABITAT: Coniferous and hardwood forests, and acid woodlands.

HARVEST: Leaves and herbs in late summer or early fall.

USES: The dried leaves are reportedly used as a diuretic, astringent, tonic, and antirheumatic.

CHIMAPHILA UMBELLATA (L.) NUTT.

(PYROLACEAE)



CHIONANTHUS VIRGINICUS L.

(OLEACEAE)

COMMON NAMES: Fringe tree, American fringe tree, flowering ash, graybeard tree, old man's beard, poison ash, shavings, snowdrop tree, snowflowers, white fringe, white fringe tree.

DESCRIPTION: A shrub or tree about 35 feet in height. Leaves are opposite. Produces many white flowers on long stems, in panicles. Berries are fleshy, globular, and purple.

FLOWERING PERIOD: April to May.

HABITAT: Damp woods, thickets, bluffs, and dry woods.

HARVEST: Root bark and fresh bark of trunks in the fall.

USES: The bark is used as a tonic, diuretic, and astringent; it is also used to reduce fever. In Appalachia a liquid of boiled root bark is applied to skin irritations.

CHIONANTHUS VIRGINICUS L.

(OLEACEAE)

CIMICIFUGA AMERICANA MICHX.

(RANUNCULACEAE)

COMMON NAMES: American bugbane, bugbane, mountain bugbane, mountain rattle-top, summer cohosh.

DESCRIPTION: A perennial shrub that grows to 3 to 4 feet in height. The plant resembles *C. racemosa* (L.) Nutt but is not as tall; and it has shorter lateral spikes of small, white flowers plus a terminal spike.

FLOWERING PERIOD: July to September.

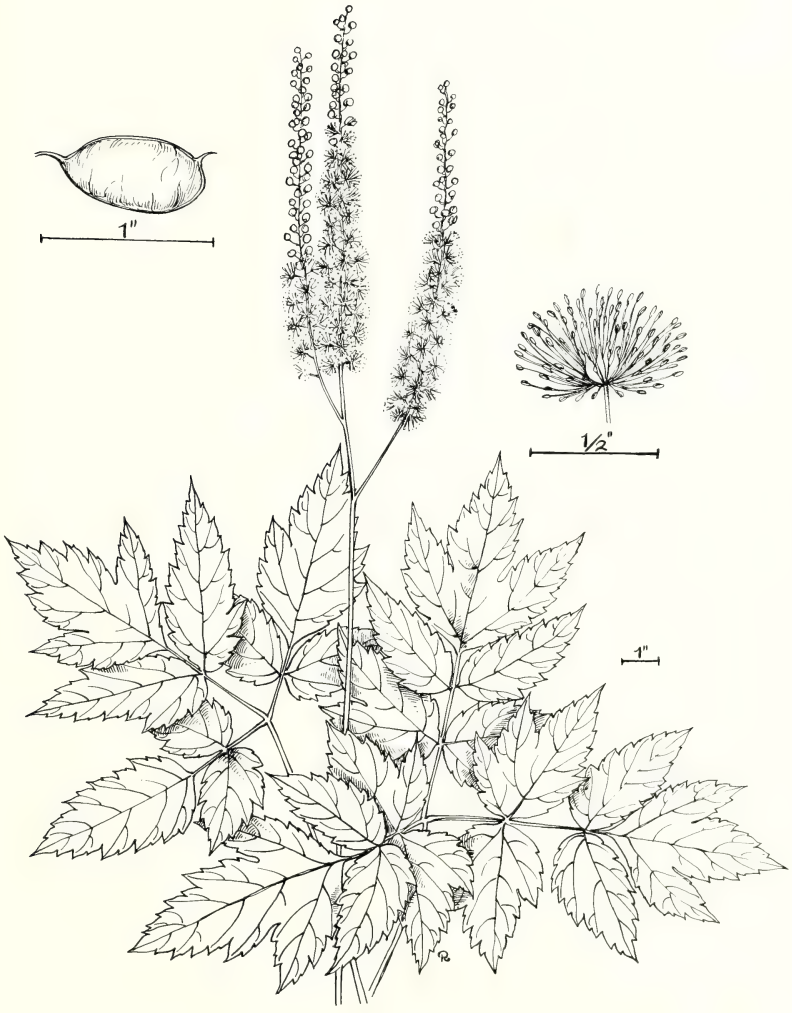
HABITAT: Moist woods.

HARVEST: Rhizomes and roots at end of growing season.

USES: This plant is used as an antispasmodic in some areas. (See *C. racemosa*.)

CIMICIFUGA AMERICANA MICHX.

(RANUNCULACEAE)



CIMICIFUGA RACEMOSA (L.) NUTT.

(RANUNCULACEAE)

COMMON NAMES: Cohosh bugbane, battle weed, black cohosh, black snakeroot, blueberry, blue ginseng, bugbane, cohosh, columbine-leaved leontice, cordate rattle-top, false cohosh, heart-leaved rattle-top, heart-leaved snakeroot, meadow rue leontice, papoose root, rattle root, rattlesnake root, rattle-top, rattleweed, richweed, squaw root, yellow ginseng.

DESCRIPTION: A perennial shrub that grows to 8 feet in height. Each of the leaf stems holds 2, 3, or 5 leaflets. The plant is topped with a slender spike of small, white flowers. The rhizome or root is knotted.

FLOWERING PERIOD: June to August.

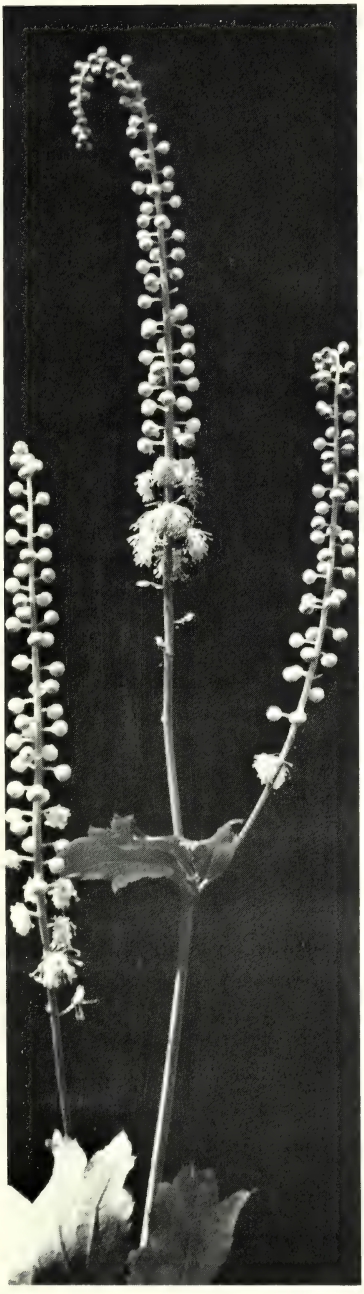
HABITAT: Rich, open woods.

HARVEST: Rhizomes and roots in the fall.

USES: The roots and rhizomes are considered valuable in treating chronic rheumatism. The plant is also used as an expectorant, astringent, emmenagogue, and bitter tonic. In Appalachia, a tea made from the root is used to treat sore throat.

CIMICIFUGA RACEMOSA (L.) NUTT.

(RANUNCULACEAE)



CNICUS BENEDICTUS L.

(ASTERACEAE)

COMMON NAMES: Blessed thistle, bitter thistle, bitterweed, blessed carduus, carduus, cursed thistle, holy thistle, our-lady's thistle, spotted carduus, spotted thistle, St. Benedict's thistle.

DESCRIPTION: This annual grows to about 2 feet in height. Leaves are thistle-like, toothed, lobed, and spiny. Plant produces many flowered yellow heads.

FLOWERING PERIOD: April to August.

HABITAT: Roadsides and waste places.

HARVEST: Herbs and tops in bloom; ripe seed.

USES: The upper portion of this plant has been used to treat worms; and it is also used in an emmenagogue, stimulant, tonic, and emetic. Because it is hemostatic, the seed is also useful as an emetic. In Europe, ground parts of the plant are mixed with wine for use as an aperitif.

CNICUS BENEDICTUS L.

(ASTERACEAE)

COLLINSONIA CANADENSIS L.

(LAMIACEAE)

COMMON NAMES: Citronella horse balm, broadleaf collinsonia, Canadian collinsonia, citronella, hard hack, heal-all, horse balm, horseweed, knob grass, knobroot, ox balm, richweed, stone root.

DESCRIPTION: A perennial that grows to 3 feet in height. Leaves are opposite, large, coarsely toothed, and roughly ovate in shape. Strongly scented lemon-yellow flowers are arranged vertically along opposite branches of the main stem. Plant rises from a thick, woody rhizome.

FLOWERING PERIOD: July to September.

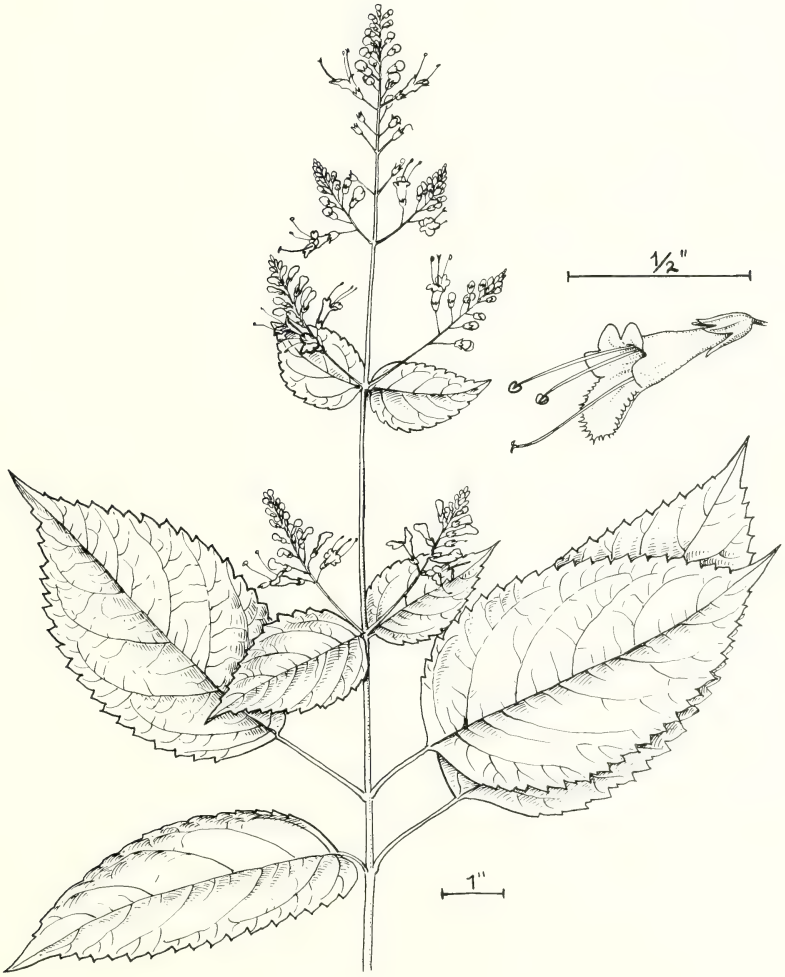
HABITAT: Rich, moist woods.

HARVEST: Herb at flowering; root in fall.

USES: Roots are used as a sedative and antispasmodic, diuretic, astringent, and tonic.

COLLINSONIA CANADENSIS L.

(LAMIACEAE)



COMPTONIA PEREGRINA (L.) COULT.

(MYRICACEAE)

COMMON NAMES: Sweet fern, Canadian sweetgale, fern bush, ferngale, ferngate, meadow fern, shrubby fern, shrubby-sweet fern, spleen fern, spleenwort bush, spleenwort fern, sweet bush, sweet ferry.

DESCRIPTION: A sweet-smelling, many-branched, perennial shrub that grows to 3 feet in height. Small branches are lightly hairy. Leaves are alternate, 3 to 6 inches long, linear, and deeply cleft. Produces fuzzy pistillate flowers in catkins, and ¼ inch shiny, brown nutlets.

FLOWERING PERIOD: April.

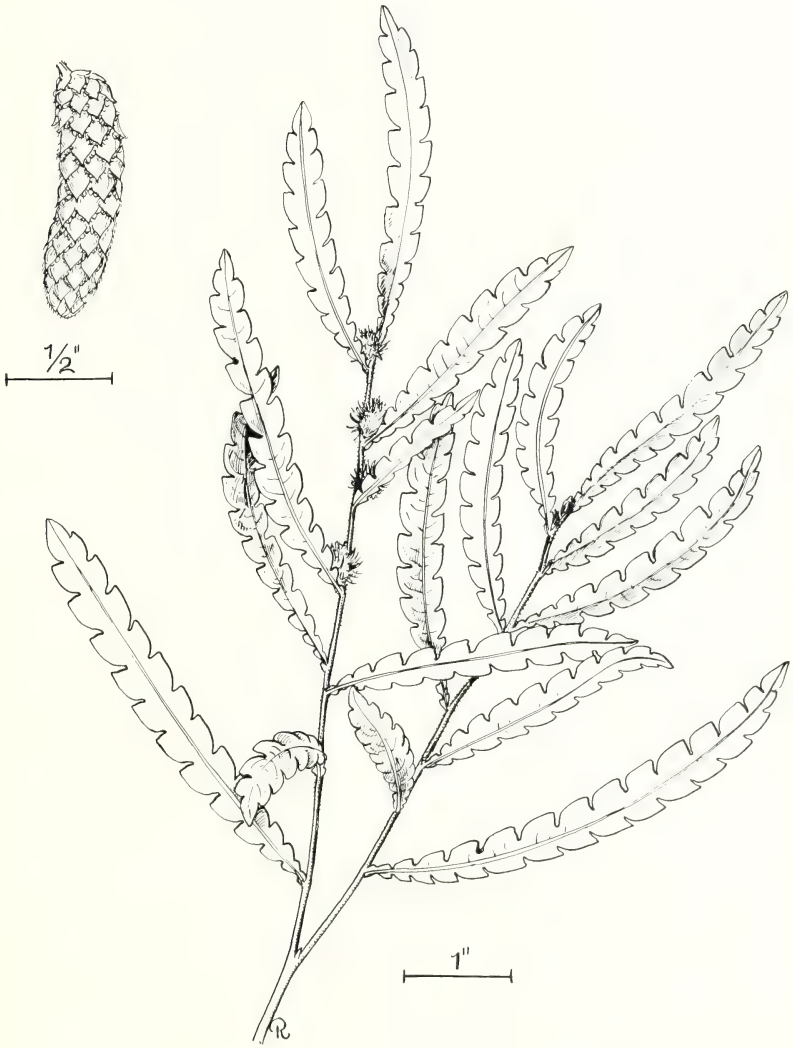
HABITAT: Open, sterile woodlands; clearings, pastures, and dry woods.

HARVEST: Leaves.

USES: The U.S. Dispensatory states that a decoction of the plant is used to treat diarrhea. Another authority says the plant has value in treating poison ivy.

COMPTONIA PEREGRINA (L.) COULT.

(MYRICACEAE)



CORALLORHIZA (CHAT.)

(ORCHIDACEAE)

COMMON NAMES: Coralroot, crawleyroot, dragon's claws.

DESCRIPTION: A perennial saprophytic orchid that has no green foliage. Produces spike-like flowering stem, with yellow, brown, or purplish flowers arranged along the stem. Rhizomes are coral-like, and clustered.

FLOWERING PERIOD: July to September.

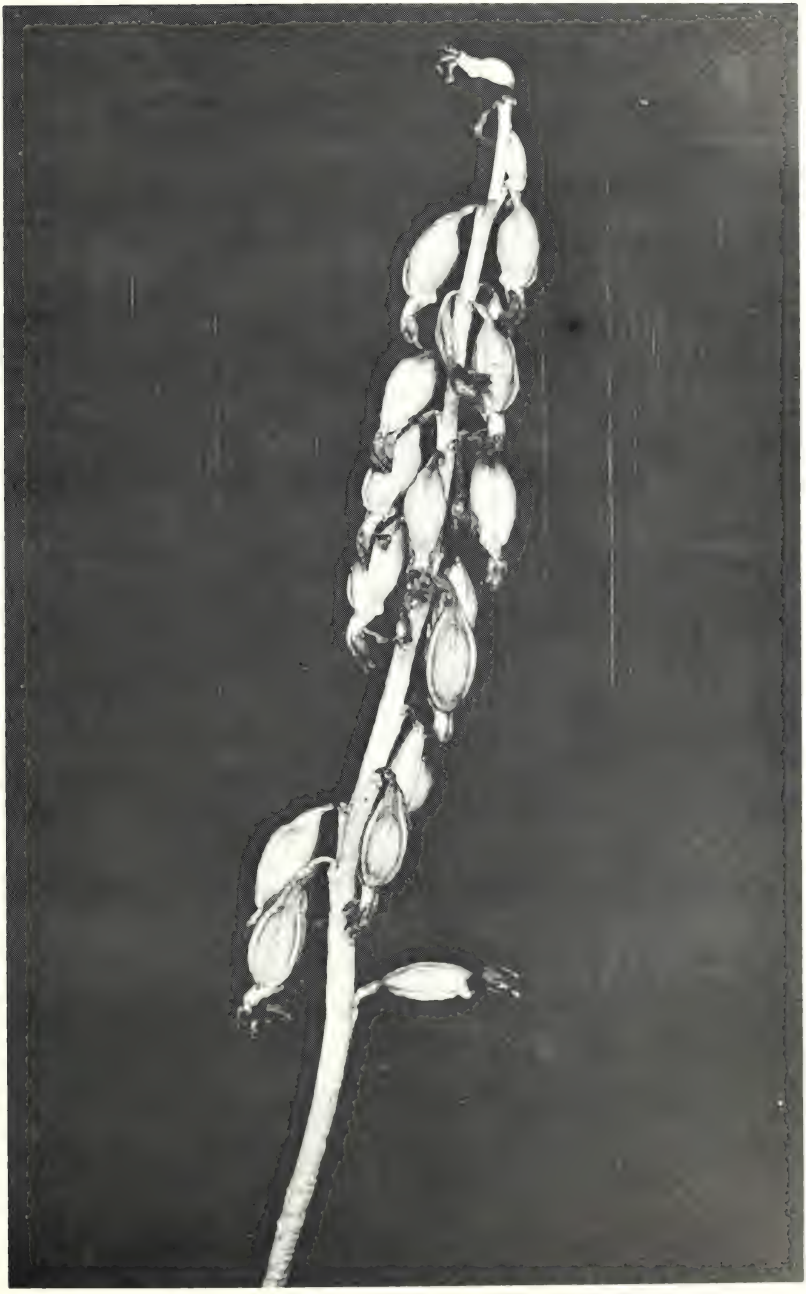
HABITAT: Uplands, damp woods, thickets, swamps, coniferous and deciduous woods.

HARVEST: Root.

USES: The plant is diaphoretic, and is used as a sedative.

CORALLORHIZA (CHAT.)

(ORCHIDACEAE)



CYPRIPEDIUM CALCEOLUS L.

var. PARVIFLORUM (SALISB.) FERN.

(ORCHIDACEAE)

COMMON NAMES: Yellow lady's slipper, American valerian, lady-slipper, nerve root, small golden slipper, small moccasin flower, small yellow lady's slipper, yellow Indian shoe, yellow moccasin.

DESCRIPTION: An aromatic perennial that grows to 4 to 28 inches in height. Ovate, alternate leaves grow from sheaths around stem of plant. It has large, sac-like yellow "slippers". Flower petals range from greenish yellow to purplish brown.

FLOWERING PERIOD: April to June.

HABITAT: Bogs and moist places.

HARVEST: Roots in fall.

USES: The plant is used as a sedative and in treating neuralgia. In Appalachia, a root tea is used to treat nervous ailments and headaches.

CYPRIPEDIUM CALCEOLUS L.

var. PARVIFLORUM (SALISB.) FERN.

(ORCHIDACEAE)

DATURA STRAMONIUM L.

(SOLANACEAE)

COMMON NAMES: Jimsonweed, apple of Peru, apple Peru, devil's trumpet, Jamestown weed, jimsonweed datura, mad apple, stink apple, stinkweed, stinkwort, stramonium, thorn apple.

DESCRIPTION: An ill-scented annual weed that grows 1 to 5 feet in height. Leaves are 4 to 6 inches long, broad, unevenly and largely toothed. Flowers are long, tubular, pale blue in leaf axils or stem forks. Plant produces large prickly capsules as fruit.

FLOWERING PERIOD: July to October.

HABITAT: Forest edge, fields, roadsides, and waste ground.

HARVEST: Leaves and tops when plant is in flower; seeds when mature.

USES: This extremely poisonous plant is used as an antispasmodic, antiasthmatic, and anodyne sedative. The dried leaves are frequently mixed with saltpeter and burned in a treatment for asthma. In Appalachia, a poultice made from blossoms is used to treat wounds and to kill pain; also, dried leaves are smoked in a pipe to relieve asthma. In the Southwest, the plant is used by Zuni Indians as a hallucogenic. In Europe, where the plant has been known for centuries, it is used to treat pulmonary disease, nervous afflictions, and nymphomania. And legend has it that the Delphic Oracle inhaled smoke from burning *Datura* leaves to induce visions.

DATURA STRAMONIUM L.

(SOLANACEAE)

DIOSCOREA VILLOSA L.

(DIOSCOREACEAE)

COMMON NAMES: Atlantic yam, China root, colicroot, devil's bones, dioscorea, rheumatism root, wild yam, yam.

DESCRIPTION: A twining perennial vine that grows to 15 feet in height. Bottom 3 leaves are sometimes whorled. Plant has an alternate heart-shaped leaf base; and stems of tiny, greenish flowers grow opposite some of the leaves. Produces triangular capsules as fruit. Rootstock is slender, infrequently branched.

FLOWERING PERIOD: May to July.

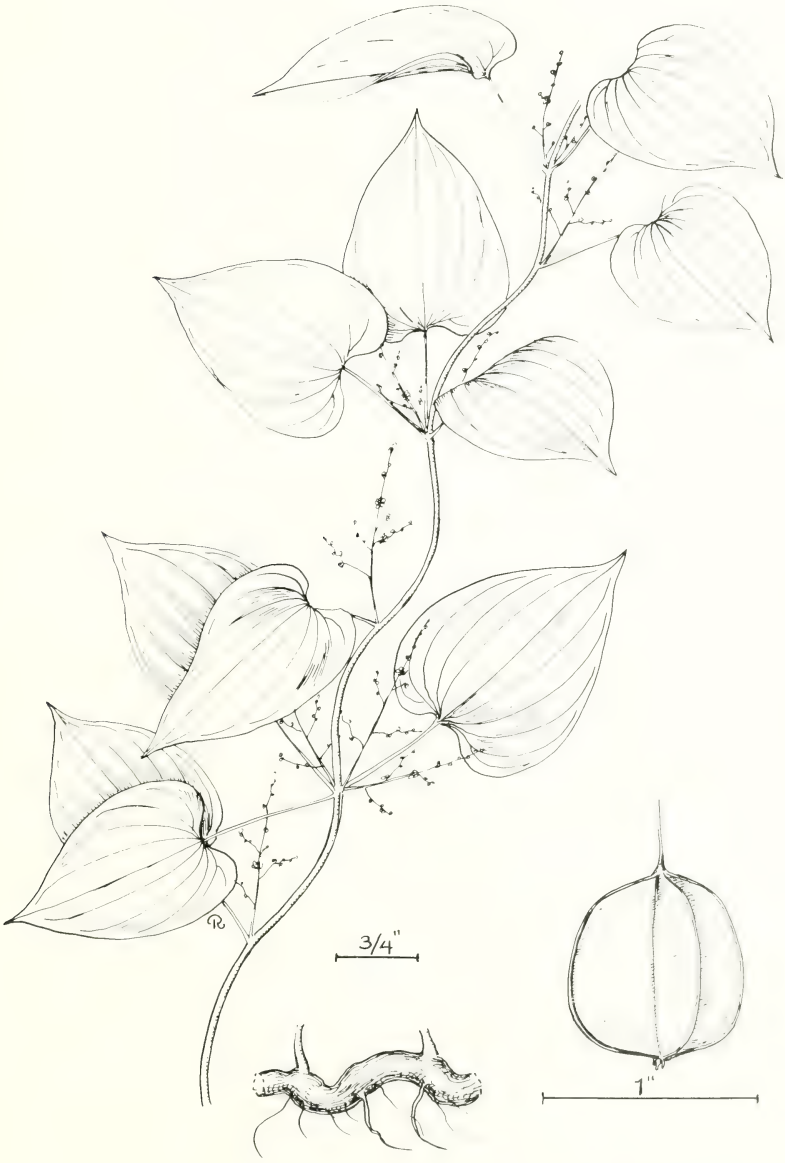
HABITAT: Deciduous woods, thickets, swamps, and wet woods.

HARVEST: Roots in fall.

USES: This herb is used as an expectorant, emetic, antispasmodic, and diaphoretic.

DIOSCOREA VILLOSA L.

(DIOSCOREACEAE)



ECHINACEA PURPUREA (L.) MOENCH

(FABACEAE)

COMMON NAMES: Purple echinacea, black Sampson, comb-flower, hedgehog, purple cone flower, red sunflower.

DESCRIPTION: A perennial that grows to 2 to 5 feet in height. Leaves are alternate, ovate to lanceolate in shape; bases contract abruptly to long, sometimes winged stems; leaf margins are toothed; and uppermost leaves have no stems. Flower heads are purple to white. Plant has thick, acid-tasting black roots.

BLOOMING PERIOD: June to August.

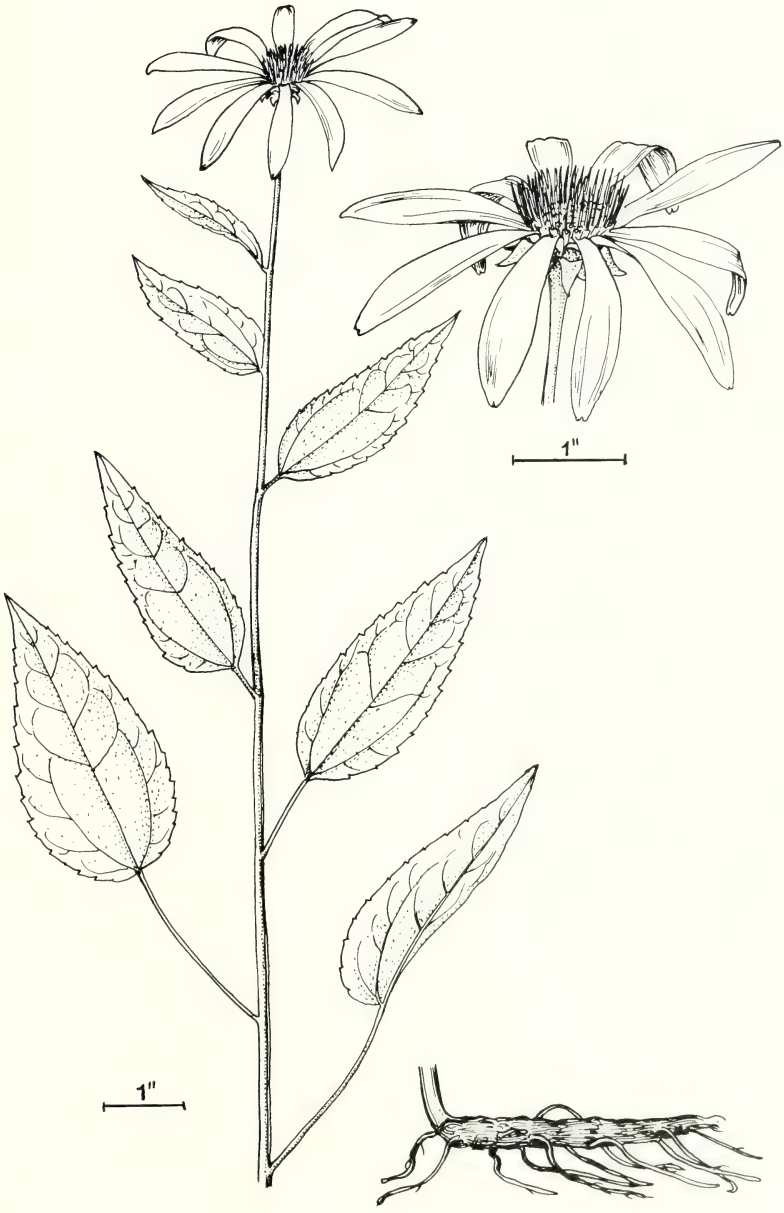
HABITAT: Dry open woods and road banks.

HARVEST: Roots in fall.

USES: U.S. Dispensatory states that this plant reportedly increases the body's resistance to infection. Tinctures of *Echinacea* species have been used in corn remedies.

ECHINACEA PURPUREA (L.) MOENCH

(FABACEAE)



ERYNGIUM AQUATICUM L.

(APIACEAE)

COMMON NAMES: Button snakeroot eryngo, button snakeroot, corn snakeroot, eryngo, feverweed, rattlesnake flag, rattlesnake master, rattlesnake weed, water eryngo.

DESCRIPTION: An erect, coarse-branched, perennial that grows to ½ to 5 feet in height. It has firm elongate-to-lanceolate lower leaves; upper leaves are sessile. The plant bears fruit from September to November.

FLOWERING PERIOD: Late July to September.

HABITAT: Fresh to brackish marshes, streams, ponds and bogs, and wet pinelands.

HARVEST: Rootstock in fall.

USES: In large doses, infusions have been used as emetics. Also used as a diaphoretic and expectorant.

ERYNGIUM AQUATICUM L.

(APIACEAE)

EUONYMUS ATROPURPUREUS JACQ.

(CELASTRACEAE)

COMMON NAMES: Eastern wahoo, American spindle tree, arrow-wood, bitter ash, bleeding heart, burning bush, bursting heart, Indian arrow-wood, pegwood, purple strawberry bush, skewerwood, spindle tree, strawberry bush, wahoo.

DESCRIPTION: A shrub or small tree that grows to 25 feet in height. It has green 4-sided branches and purplish flowers. Produces seeds in prominent scarlet 4-lobed fruit.

FLOWERING PERIOD: May to July.

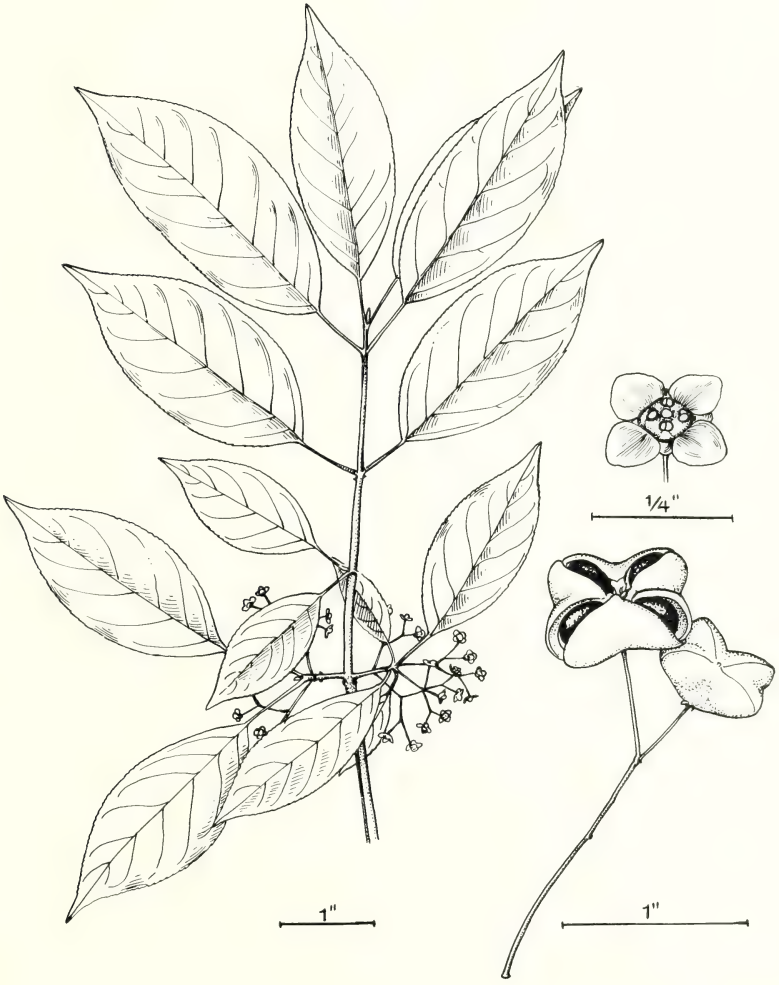
HABITAT: Rich woods and thickets, stream banks, swamps, and forests.

HARVEST: Bark of root and stem any time of the year.

USES: The bark is reported to be of value as a drastic purgative.

EUONYMUS ATROPURPUREUS JACQ.

(CELASTRACEAE)



EUPATORIUM PERFOLIATUM L.

(ASTERACEAE)

COMMON NAMES: Boneset, ague-weed, common boneset, crosswort, feverwort, Indian sage, Joepye, sweating plant, sweating weed, teagel, thorough-stem, thoroughwax, thoroughwort, throughstem, vegetable antimony, wild Isaac, wild sage.

DESCRIPTION: A perennial that grows to 1 to 5 feet in height. Heavy stems are lightly hairy. Leaves are opposite, and grow completely together at the base. Produces flat heads of white- or purple-tinged flowers.

FLOWERING PERIOD: Late July to October.

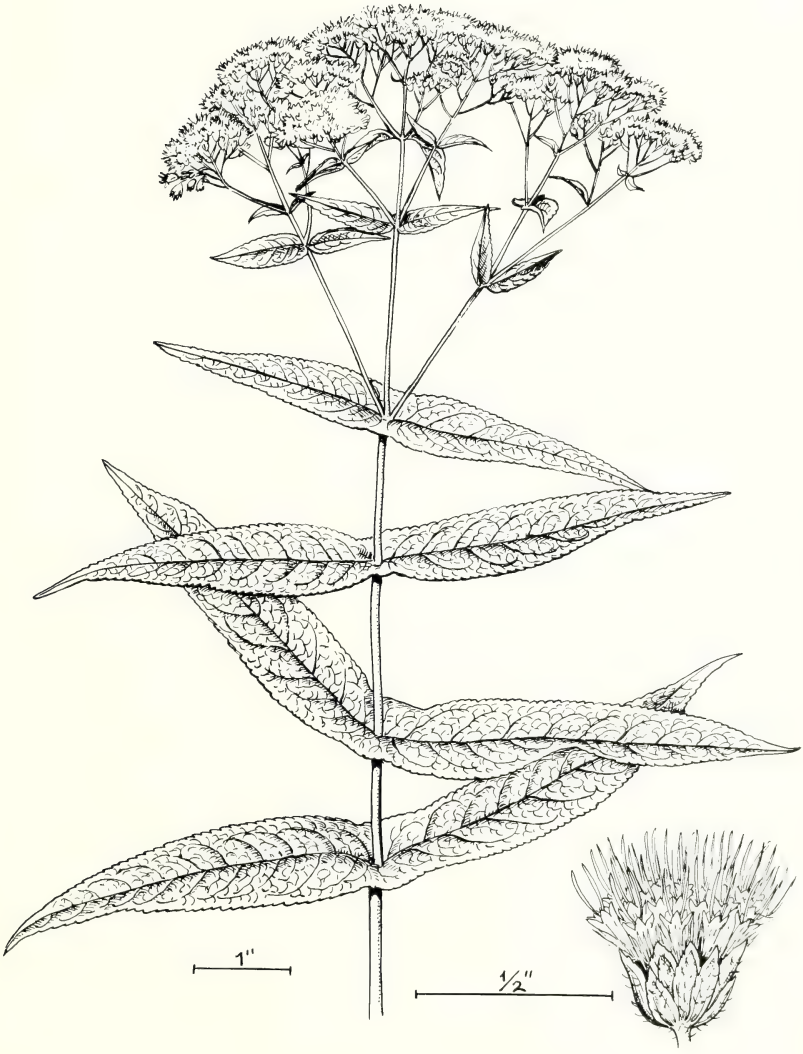
HABITAT: Swamps, marshes, low ground, alluvial woods, damp areas, and pastures.

HARVEST: Herb in spring, leaves and flowering tops in late summer (Avoid coarse stems.)

USES: This plant is used as a stimulant to promote digestion, strengthen the viscera, and restore body tone. It is also considered sudorific, alterative, antiseptic, cathartic, emetic, febrifuge, diuretic, and astringent. In Appalachia, a tea made of the leaves is used to treat coughs and consumption, and it is used as a laxative.

EUPATORIUM PERFOLIATUM L.

(ASTERACEAE)



EUPATORIUM PURPUREUM L.

(ASTERACEAE)

COMMON NAMES: Bluestem Joe-pyeweed, gravelroot, green-stemmed Joe-pyeweed, hempweed, Indian gravelroot, Joe-pyeweed, jopiroot, jopiweed, kidneyroot, king-of-the-meadow, marsh milkweed, motherwort, niggerweed, purple boneset, purple thoroughwort, queen-of-the-meadow, quill-wort, stinkweed, sweet Joe-pyeweed, tall boneset, trumpet-weed.

DESCRIPTION: This perennial grows to 3 to 10 feet in height. Leaves are in two's and five's, and in whorls to 1 foot long; they are coarsely toothed, and smell like vanilla. Stem is solid in cross-section and tinged with purple. Heads of flowers range from creamy white to purple-tinged.

FLOWERING PERIOD: July to September.

HABITAT: Rich, dry to moist, chiefly calcareous woods.

HARVEST: Rhizome in fall; leaves and flowering tops in summer and fall (Avoid coarse stems.)

USES: This plant is used for urinary disorders. The roots and herb are diuretic, stimulant, tonic, and astringent; they were used by American Indians, who also used the fruit for red or pink dye.

EUPATORIUM PURPUREUM L.

(ASTERACEAE)

FRAGARIA VIRGINIANA DUCHESNE.

(ROSACEAE)

COMMON NAMES: Virginia strawberry, Indian strawberry, scarlet strawberry, strawberry, wild strawberry.

DESCRIPTION: A low-running perennial with 3 ovate toothed leaflets. The flowers have 5 white petals, and the fruit is red.

FLOWERING PERIOD: March to June or later.

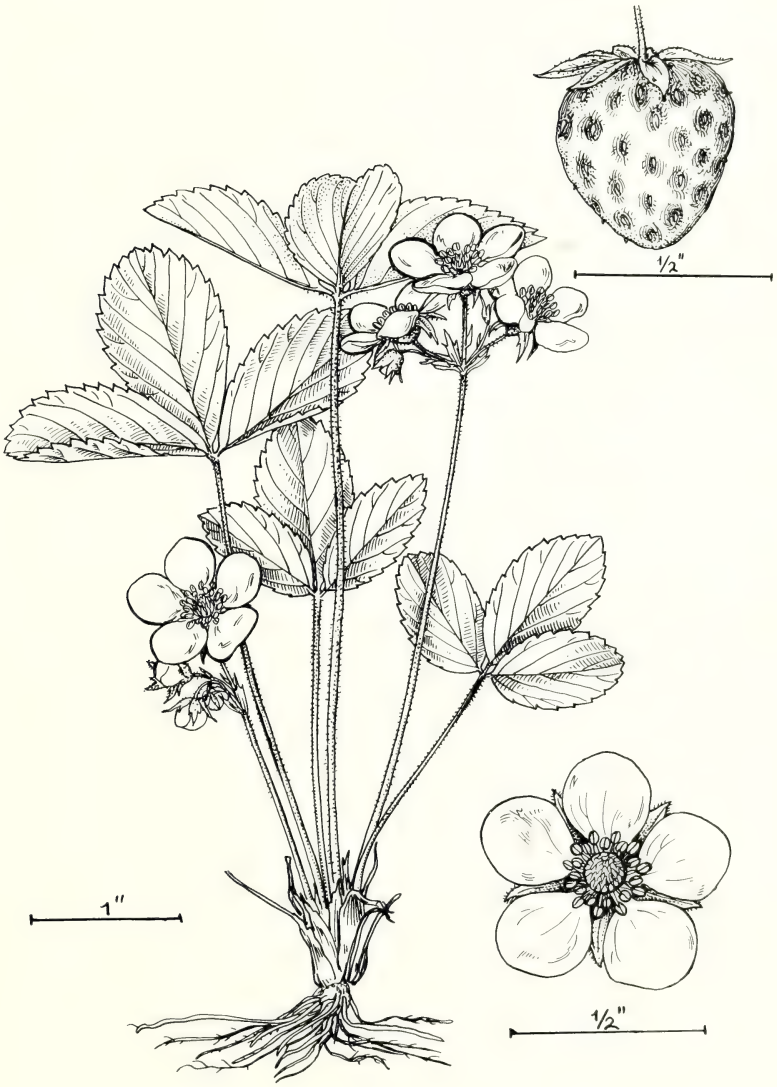
HABITAT: Fields, open slopes, borders of woods.

HARVEST: Leaves and fruit.

USES: Leaves of this plant are mildly astringent; the fruit has been used as an old-time gout remedy and refrigerant.

FRAGARIA VIRGINIANA DUCHESNE.

(ROSACEAE)



FRAXINUS AMERICANA L.

(OLEACEAE)

COMMON NAMES: White ash, American ash, American white ash, ash, biltmore ash, biltmore white ash, cane ash, smallseed white ash.

DESCRIPTION: A tree that grows to 120 feet in height. Bark is ashy gray and furrowed. Leaves are 8 to 12 inches long, with 5 to 9 (mostly 7) leaflets 3 to 5 inches long, rounded at the base and about half as wide as they are long. The winged seeds are from 1 to 3 inches long, narrow, flat, and one-seeded; and they occur in clusters.

FLOWERING PERIOD: April to May.

HABITAT: Rich upland to lowland woods, lower to middle slopes.

HARVEST: Inner bark of trunk and roots, and stem in the spring.

USES: The bark of this plant is tonic, cathartic, diuretic, a febrifuge, diaphoretic, astringent, antiarthritic, and alterative. It has been prescribed for headache followed by fever, fever sores of the lips, and constipation. In Appalachia, the chewed bark is used as a poultice on sores, and a tea made from the buds is used for snakebite.

FRAXINUS AMERICANA L.

(OLEACEAE)

GALIUM APARINE L.

(RUBIACEAE)

COMMON NAMES: Catchweed bedstraw, bedstraw, catchweed, cheese rennet herb, chicus, clabbergrass, cleavers, cleaver's herb, cleaves, cleverwort, goosegrass, goose's hare, milksweet, poor robin, savoyan, scratchweed, spring cleavers, turkey grass.

DESCRIPTION: An annual that has a weak, reclining, bristly 4-angled stem, with hairy joints. Leaves occur in whorls of 8. Flowers are white in cymes. Fruit is very bristly.

FLOWERING PERIOD: May to July.

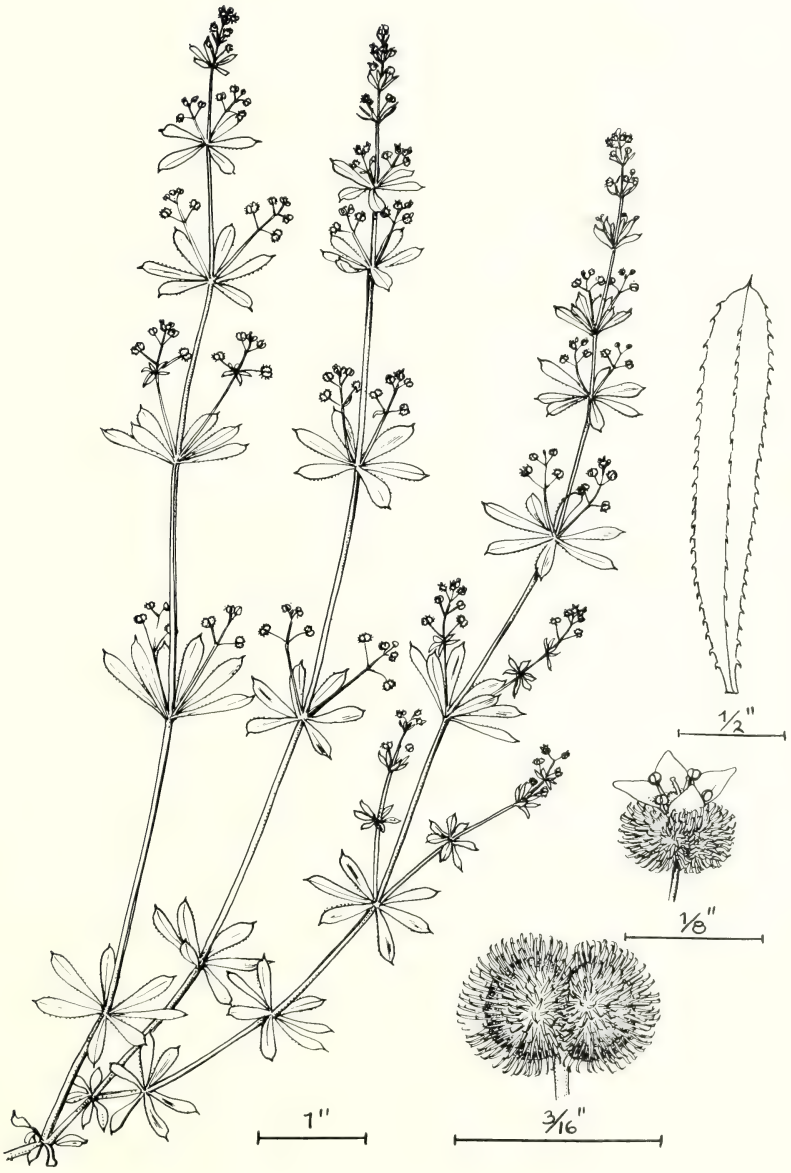
HABITAT: Rich woods, thickets, seashores, waste ground, and shady areas.

HARVEST: Herb in May and June, during flowering.

USES: The U. S. Dispensatory lists the plant as an anti-scorbutic. The herb is also a diuretic, tonic, astringent, antispasmodic; and it is used to treat inflammation of the kidneys and bladder. The seeds are used as a coffee substitute in Sweden; and the dried plant is used as a tea in some countries.

GALIUM APARINE L.

(RUBIACEAE)



GAULTHERIA PROCUMBENS L.

(ERICACEAE)

COMMON NAMES: Checkerberry wintergreen, aromatic wintergreen, berried tea, boxberry, Canadian tea, checkerberry, chequerberry, chidkerberry, clink, creeping wintergreen, deerberry, dewberry, ground holly, ground ivy, grouse berry, hillberry, ivory plum, mountain berry, mountain tea, mountain teaberry, partridge berry, pigeonberry, red-berry tea, red pollom, roxberry, spiceberry, spicy wintergreen, spring wintergreen, teaberry, three-leaved wintergreen, trailing gaultheria, wax cluster, winterberry, wintergreen.

DESCRIPTION: A low, creeping, aromatic, evergreen shrub, with 2- to 6-inch branches. Leaves are shiny and waxy. Single white, nodding flowers are in racemes in axils. Produces bright red berries in fall and winter.

FLOWERING PERIOD: June to August.

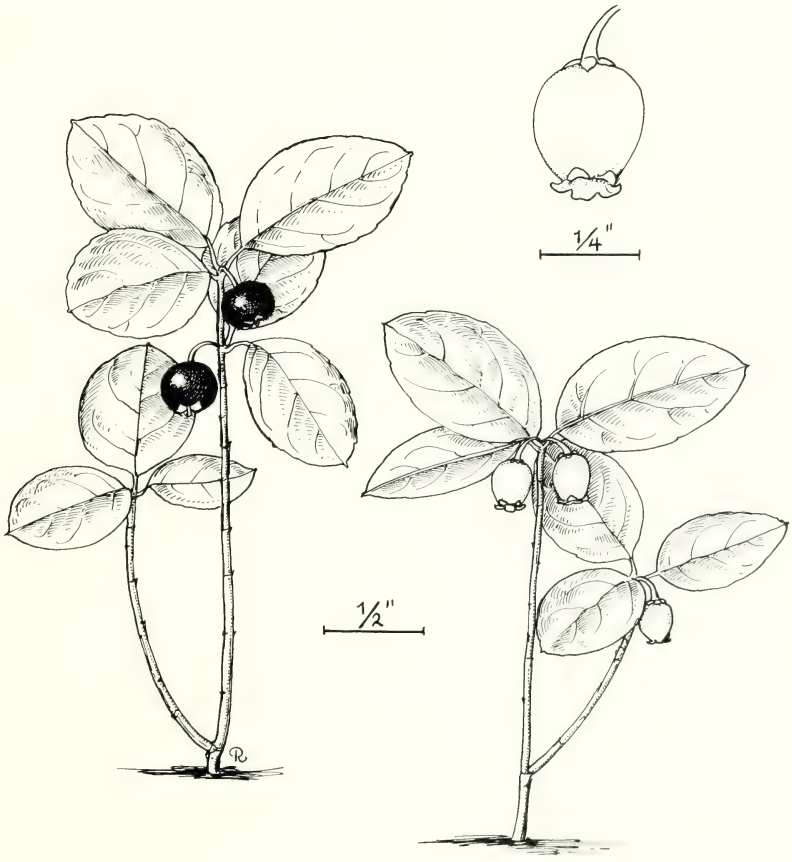
HABITAT: Sterile woods and clearings, dry wooded areas; commonly found growing with rhododendron, mountain laurel, and other members of the heath family.

HARVEST: Herb and leaves in fall.

USES: The plant is primarily a source of true wintergreen oil, which is used as a flavor, counterirritant, astringent, and carminative. Wintergreen oil is extremely toxic if consumed internally.

GAULTHERIA PROCUMBENS L.

(ERICACEAE)



GELSEMIUM SEMPERVIRENS (L.) AIT.

(LOGANIACEAE)

COMMON NAMES: Yellow jessamine, Carolina jessamine, evening trumpet flower, false jasmine, false jessamine, gelsemium, jasmine, wild jasmine, wild jessamine, woodbine, yellow jasmine root.

DESCRIPTION: A perennial vine with horizontal, branched, cylindrical rootstock. Leaves are short-stalked, lanceolate, aromatic, and evergreen, with smooth margins. Flowers are showy, fragrant, and tubular.

FLOWERING PERIOD: March to May.

HABITAT: Thickets, roadsides, fence rows, dry and damp woods, and sandy areas.

HARVEST: Roots and rhizomes just after flowering in fall.

USES: This is a very poisonous plant. Preparations made from the roots and rhizomes have been used as central nervous-system depressants, febrifuge, anodyne, and antispasmodic.

GELSEMIUM SEMPERVIRENS (L.) AIT.

(LOGANIACEAE)

GENTIANA VILLOSA L.

(GENTIANACEAE)

COMMON NAMES: Sampson's snakeroot, marsh gentian, straw-colored gentian, striped gentian.

DESCRIPTION: A perennial with several smooth ascending stems. Leaves are oblanceolate. A cluster of crowded, tubular, greenish-white to purplish-green flowers is found at top of the plant.

FLOWERING PERIOD: August to October.

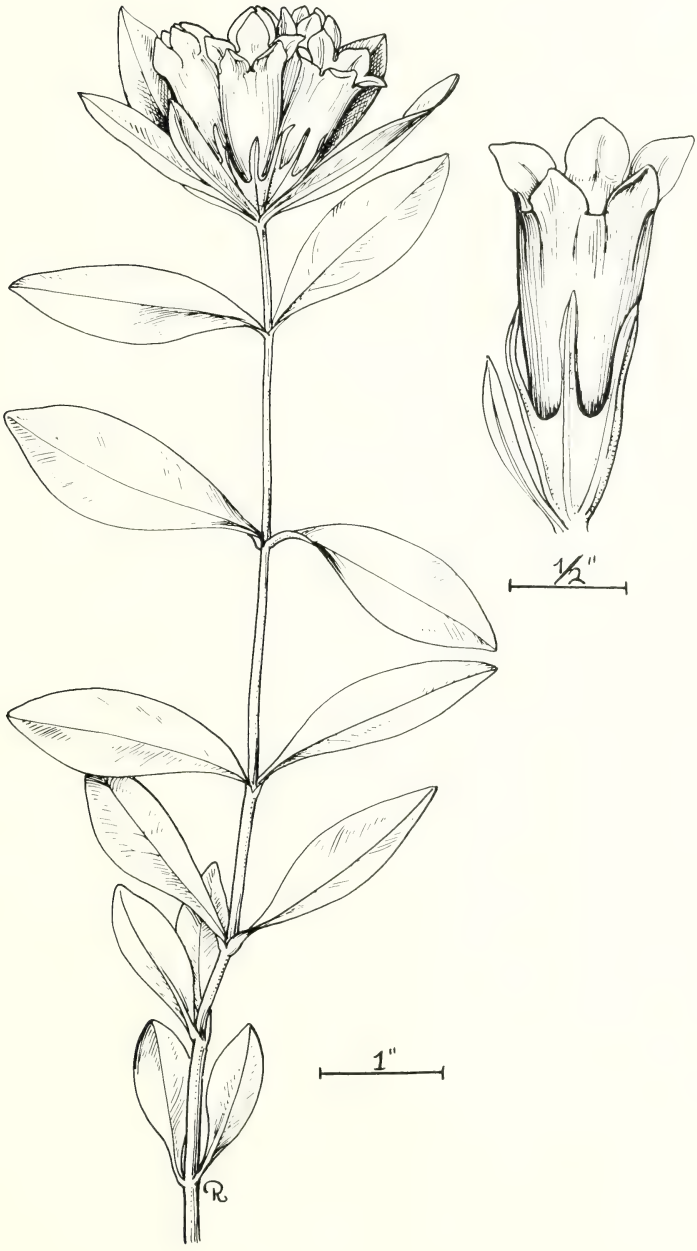
HABITAT: Meadows, brooksides, slopes, calcareous rocks, woods, and pinelands.

HARVEST: Root in fall.

USES: The rhizome has been used to treat indigestion, gout, and rheumatism; and it has also been used as an antiemetic. Because of its bitter flavor, probably the most useful application of this plant is as a tonic and astringent. In Appalachia, a root tea is drunk as a tonic, and a piece of the root is sometimes worn or carried to increase one's physical powers.

GENTIANA VILLOSA L.

(GENTIANACEAE)



GERANIUM MACULATUM L.

(GERANIACEAE)

COMMON NAMES: Spotted geranium, alum bloom, alumroot, American kind, American tormentil, astringent root, chocolate flower, common crane's bill, cranesbill, cranesbill geranium, crowfoot, dove's foot, old maid's-nightcap, shameface, spotted cranesbill, stork bill, tormentil, wild cranesbill, wild geranium.

DESCRIPTION: A perennial 1 to 2 feet in height, with a single stem and thick rhizomes. Leaves are 3 to 6 inches across, and deeply cleft. Produces 3 to 5 loose, rosy-purple to white flowers, 1 inch across.

FLOWERING PERIOD: April to June.

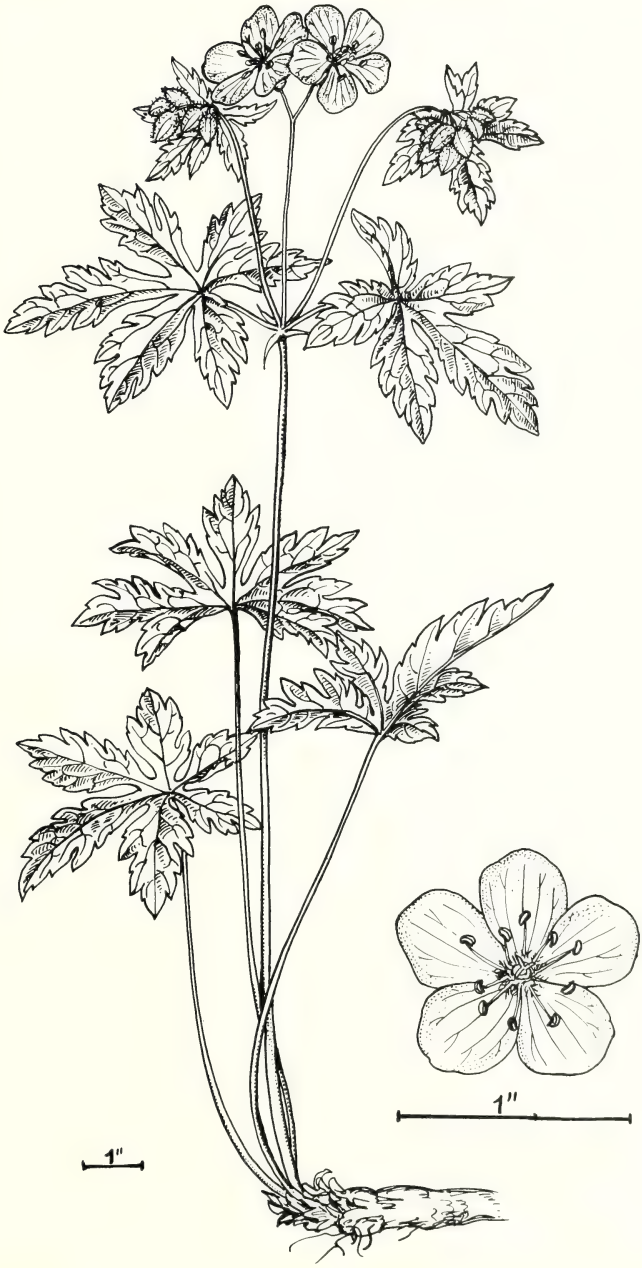
HABITAT: Rich woods and meadows.

HARVEST: Leaves and rhizomes in spring, just before plant flowers, or in late summer.

USES: The leaves have been used as a vulnerary. However, the roots and rhizomes, which contain much tannin, are very astringent, antiseptic, styptic, and diuretic; and they have been used to treat diarrhea. In Appalachia, a tea made from the whole plant is used to treat dysentery and sore throat.

GERANIUM MACULATUM L.

(GERANIACEAE)



HAMAMELIS VIRGINIANA L.

(HAMAMELIDACEAE)

COMMON NAMES: Witch hazel, common witch hazel, hamamelis, long boughs, pistachio, snapping hazel, snapping hazel-nut, southern witch hazel, spotted alder, striped alder, tobacco wood, white hazel, winterbloom, wood tobacco.

DESCRIPTION: A crooked tree or shrub usually 8 to 15 feet in height, with forking branches and smooth, brown bark. The leaves are roundish to round-oval, 3 to 5 inches long, thick, and borne on a short stalk. Yellow, thread-like flowers appear in late fall or early winter after the leaves have fallen. Fruits occur in clusters along the stem and mature the following season, when they burst open and eject shiny black seeds.

FLOWERING PERIOD: September to November.

HABITAT: Dry to moist woods.

HARVEST: Leaves, twigs, and bark in fall.

USES: The twigs, leaves, and bark are used to prepare witch hazel extract, which has been used in shaving lotions and to treat bruises and sprains. The fresh leaves of the plant contain high concentrations of tannin, which makes them very astringent.

HAMAMELIS VIRGINIANA L.

(HAMAMELIDACEAE)

HEDEOMA PULEGIOIDES (L.) PERS.

(LAMIACEAE)

COMMON NAMES: American pennyroyal, American false-pennyroyal, mock pennyroyal, pennyroyal, pennyroyal of America, pudding grass, squaw mint, stinking balm, thick-weed, tickweed.

DESCRIPTION: A branched annual that grows to 18 inches in height. Leaves are erect, hairy, small, and ovate, with the broad end at the base. Produces clusters of aromatic, tiny, bluish flowers about 1/4 inch long.

FLOWERING PERIOD: July to September.

HABITAT: Dry soils, woodlands, pastures, and meadows.

HARVEST: Leaves, flowering tops and small stems in full bloom; plants just before flowering.

USES: This herb is used as an antispasmodic, rubifacient, and stimulant. A tea is used in Appalachia for treating pneumonia.

HEDEOMA PULEGIOIDES (L.) PERS.

(LAMIACEAE)

HEPATICA ACUTILOBA DC.

(RANUNCULACEAE)

COMMON NAMES: Sharplobe hepatica, heart liverleaf, hepatica, liverleaf, liverwort, noble liverwort, sharplobed liverleaf.

DESCRIPTION: A perennial that grows to 9 inches in height. Liver-shaped leaves have 3 to 5 lobes, and each leaf stalk has one leaf. Produces a single white to purplish flower in spring.

FLOWERING PERIOD: March to April.

HABITAT: Rich calcareous woods.

HARVEST: Leaves in the spring.

USES: This herb has been used as a tonic, mild astringent, and diuretic.

HEPATICA ACUTILOBA DC.

(RANUNCULACEAE)

HYDRANGEA ARBORESCENS L.

(SAXIFRAGACEAE)

COMMON NAMES: Smooth hydrangea, sevenbark, wild hydrangea.

DESCRIPTION: A perennial shrub that grows to 10 feet in height, with stems rising from base of the plant. It has large, opposite, ovate leaves, and produces white or greenish flowers at top of branches. Many varieties are recognized.

FLOWERING PERIOD: May to July.

HABITAT: Rich woods, calcareous rocky slopes, banks of streams.

HARVEST: Root in the fall.

USES: The roots and rhizomes have been used as diuretics, cathartics, and tonics. Some authorities say that the drug has value in preventing kidney stones.

HYDRANGEA ARBORESCENS L.

(SAXIFRAGACEAE)

HYDRASTIS CANADENSIS L.

(RANUNCULACEAE)

COMMON NAMES: Goldenseal, eyebalm, eyebright, eyeroot, goldenroot, ground raspberry, hydrastis, Indiana dye, Indian paint, Indian plant, Indian turmeric, jaundice root, Ohio curcuma, orange root, tumeric, wild turmeric, yellow eyewright, yellow paintroot, yellow puccoon, yellowroot, yellowwort.

DESCRIPTION: A perennial that grows to 1 foot in height. It has 1 stem with two 5- to 7-lobed leaves near the apex, which is topped with 1 greenish-white flower. Several single leaf stocks topped with flowers that have no petals rise from the roots. Fruit looks like a raspberry but is inedible.

FLOWERING PERIOD: April to May.

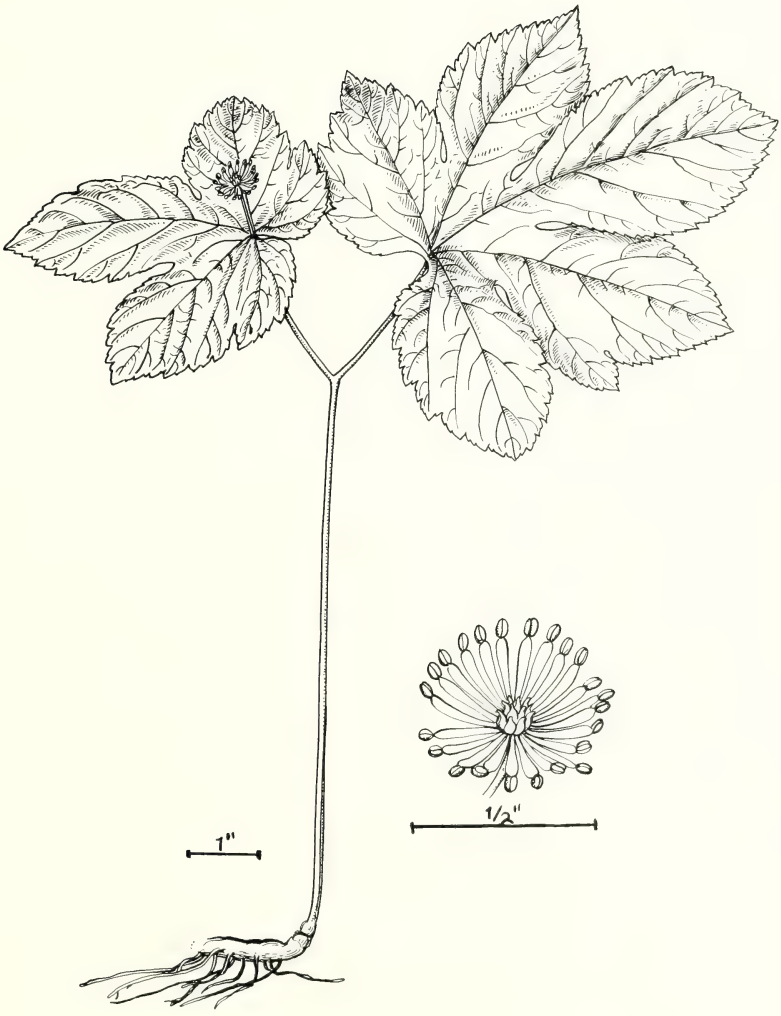
HABITAT: Rich woods.

HARVEST: Rootstock in fall; leaves or tops in late summer or fall, after seeds ripen.

USES: The pulverized rhizomes and roots have been used a long time to treat mouth ulcers, and as a hemostatic. This preparation has also been used as a diuretic in catarrhal conditions, and as an astringent for treating certain eye conditions. In Appalachia, a root tea is used as a tonic.

HYDRASTIS CANADENSIS L.

(RANUNCULACEAE)



JEFFERSONIA DIPHYLLA (L.) PERS.

(BERBERIDACEAE)

COMMON NAMES: American twinleaf, ground squirrel pea, helmet pod, rheumatism root, twinleaf, yellow root.

DESCRIPTION: An erect shrub that grows to 2 feet. Stalk is topped by 2 identical, opposite, half-ovate leaf segments. Flowers are white, 1 inch across. Fruit is a large capsule.

FLOWERING PERIOD: March to April.

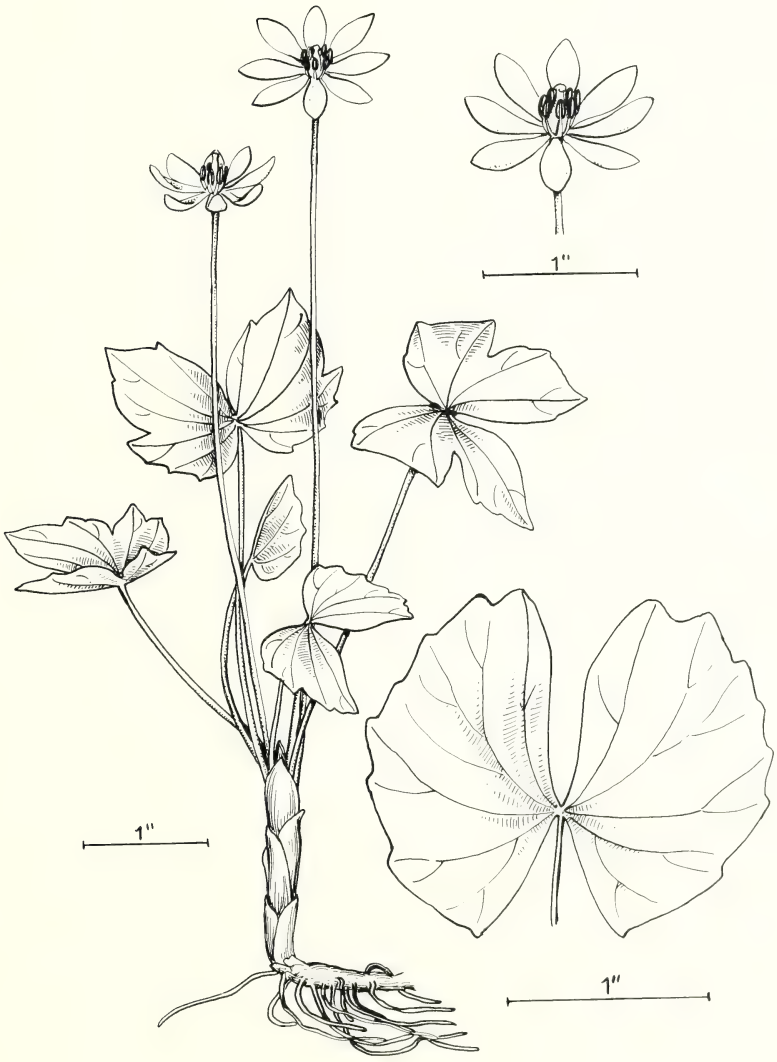
HABITAT: Rich, damp, shaded woods.

HARVEST: Root in fall.

USES: The rhizomes and roots have been used to treat chronic rheumatism, dropsy, spasms, and as a gargle. In small doses, the drug is an expectorant; in large doses it is an emetic. It also has been considered a diuretic, alterative, and antispasmodic.

JEFFERSONIA DIPHYLLA (L.) PERS.

(BERBERIDACEAE)



JUGLANS CINEREA L.

(JUGLANDACEAE)

COMMON NAMES: Butternut, filnut, lemonnut, oilnut, white walnut.

DESCRIPTION: A tree usually 40 to 60 feet in height, with light gray bark divided into broad, flat ridges by moderately deep furrows. Leaves are compound with 11 to 17 leaflets arranged opposite each other, from 2 to 3 inches long, and with very short stems. Elliptical pointed fruit is 1½ to 2½ inches long and occurs in clusters of 2 to 5 or singly. The strong smelling, sticky husk is covered with hairs and contains an edible nut that has a hard, thick, deeply furrowed shell.

FLOWERING PERIOD: April to June.

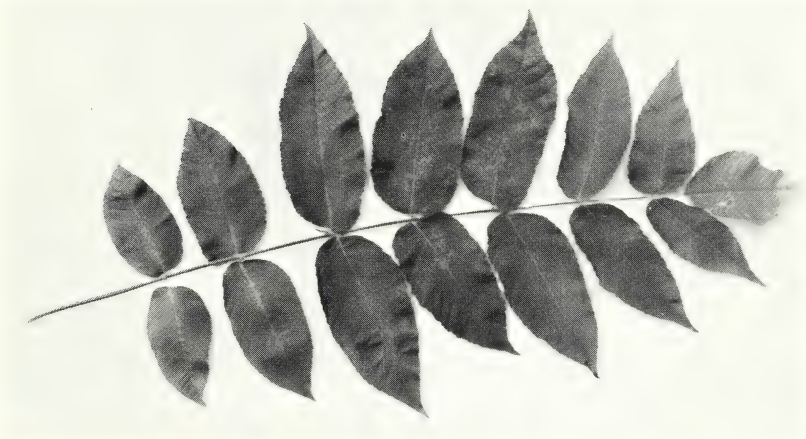
HABITAT: Rich woods and along rivers on well drained soils.

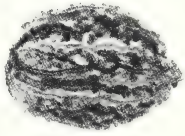
HARVEST: Inner bark of root any time of year; leaves and nuts in the fall.

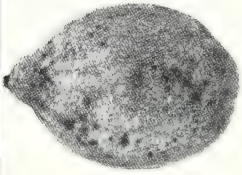
USES: The bark has been used as a rubifacient and cathartic. Oil extracted from the fruit is reportedly valuable in treating tape worms and fungus infections. In Appalachia, a tea made from the bark is used as a laxative.

JUGLANS CINEREA L.

(JUGLANDACEAE)







JUGLANS NIGRA L.

(JUGLANDACEAE)

COMMON NAMES: Black walnut, American walnut, eastern black walnut, walnut.

DESCRIPTION: A valuable tree that often grows to more than 120 feet in height, with almost black bark divided into rough ridges by deep, narrow furrows. Leaflets are alternate, commonly 12 to 23 per stem, finely toothed, and 3 to 3½ inches long. The fruit occurs singly or in clusters of 2 or 3, and has a thick, somewhat fleshy, aromatic husk; the fruit is roundish, about 1½ to 2 inches in diameter, edible, and has a hard, rough, deeply furrowed shell.

FLOWERING PERIOD: April to June.

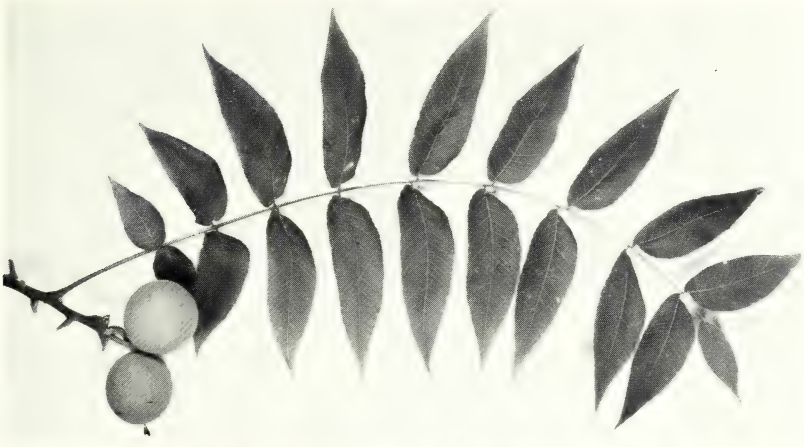
HABITAT: Rich woods and limestone soils.

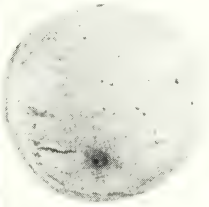
HARVEST: Inner bark of root; leaves and nuts in fall.

USES: The root bark is cathartic. A leaf infusion is used as an astringent and against bedbugs.

JUGLANS NIGRA L.

(JUGLANDACEAE)





JUNIPERUS COMMUNIS L.

(PINACEAE)

COMMON NAMES: Common juniper, dwarf juniper, gorst, ground juniper, hackmatack, horse savin, juniper, juniper bush, prostrate juniper.

DESCRIPTION: A small evergreen shrub or tree 12 to 30 feet in height, low and spreading or upright. The bark of trunk is shreddy and reddish brown. Needles are straight, sharp-pointed, ridged, and nearly at right angles to branchlets. Dark purple fruit is round, fleshy, berry-like, and about ¼ inch in diameter.

FLOWERING PERIOD: March.

HABITAT: Dry soil.

HARVEST: Fruit in fall and winter.

USES: The fruit is used commercially in flavoring gin, and has value as a diuretic and urinary antiseptic. In Europe, it is used to treat arteriosclerosis.

JUNIPERUS COMMUNIS L.

(PINACEAE)

JUNIPERUS VIRGINIANA L.

(PINACEAE)

COMMON NAMES: Eastern redcedar, Carolina cedar, cedar, cedar apple, evergreen, juniper, pencil cedar, red cedar, red juniper, red savin, savin, Virginia cedar.

DESCRIPTION: A small erect evergreen tree 20 to 50 feet in height. Trunk is lobed, buttressed, and has thin, red-tinged, fibrous, peeling bark. Foliage has needle and scale form. Produces smooth, round, berry-like bluish fruit with 1 or 2 seeds.

FLOWERING PERIOD: February to March.

HABITAT: Pasture land; dry, rarely wet, open woods; or calcareous rocky slopes and barrens.

HARVEST: Leaves and mature fruits.

USES: The leaves have been used as a stimulant, emmenagogue, and taeniafuge. In Appalachia, a mixture of nuts, leaves, and twigs is boiled and inhaled as a treatment for bronchitis. In New Mexico, some Spanish-speaking people use a boiled mixture of bark and water to treat skin rash.

JUNIPERUS VIRGINIANA L.

(PINACEAE)

LACTUCA SCARIOLA L.

(ASTERACEAE)

COMMON NAMES: Prickly lettuce, compass plant, wild lettuce, wild opium.

DESCRIPTION: An annual or perennial that grows to 2 feet in height. Flowers are yellow, but purple or bluish when dried. Stem has a few prickles. Leaves are cleft, with lobes arranged on either side of a common axis.

FLOWERING PERIOD: June to October.

HABITAT: Cultivated fields, waste or disturbed areas, dry soil, and gardens.

HARVEST: Leaves in summer or fall; milky juice of the stem in summer.

USES: The milky juice of this plant is extremely irritating to the eyes. The whole herb has been used as a diuretic, antispasmodic, and emollient.

LACTUCA SCARIOLA L.

(ASTERACEAE)

LEONURUS CARDIACA L.

(LAMIACEAE)

COMMON NAMES: Motherwort, common motherwort, lion's ear, lion's tail, lion's tart, throwwort.

DESCRIPTION: A perennial that grows to 3 to 6 feet in height. Stems are stout, with 2- to 5-inch long petioled leaves. The palmately lobed leaves have sharp teeth. Flowers are white to pink, and very hairy.

FLOWERING PERIOD: May to August.

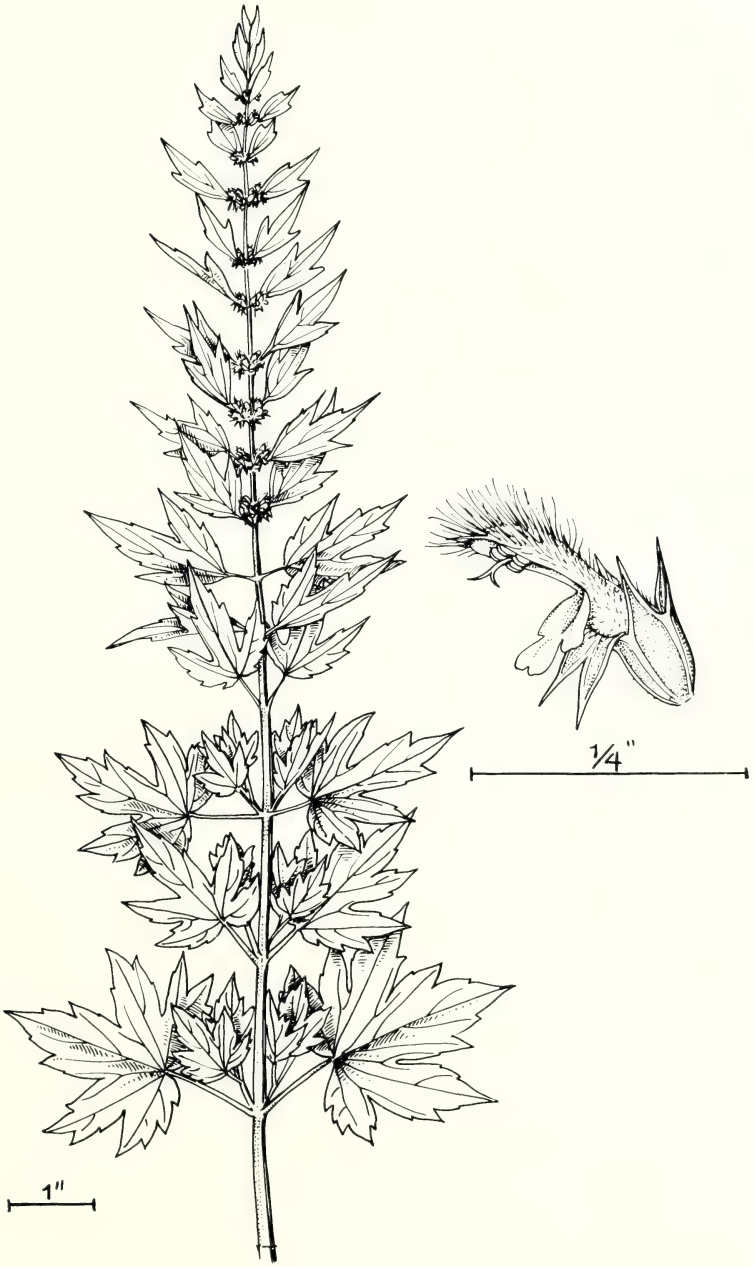
HABITAT: Waste places, roadsides, gardens, and pastures.

HARVEST: Herb at flowering time.

USES: The herb is used as a stimulant and emmenagogue. In Europe it has been used to treat heart palpitations and asthma.

LEONURUS CARDIACA L.

(LAMIACEAE)



LINDERA BENZOIN (L.) BLUME

(LAURACEAE)

COMMON NAMES: Common spicebush, allspice bush, Benjamin bush, feverbush, spiceberry, spicebush, wild allspice.

DESCRIPTION: A deciduous shrub that grows to more than 15 feet in height. Leaves are 3 to 5 inches long, alternate, elliptical, aromatic, with smooth margins. Produces greenish-yellow flowers in dense clusters and long, bright red berries.

FLOWERING PERIOD: March to May.

HABITAT: Damp woods and brooksides.

HARVEST: Bark and twigs.

USES: The aromatic bark is used to treat dysentery, coughs, and colds; and it is used as a vermifuge.

LINDERA BENZOIN (L.) BLUME

(LAURACEAE)

LIQUIDAMBAR STYRACIFLUA L.

(HAMAMELIDACEAE)

COMMON NAMES: Sweetgum, American storax, American sweetgum, bilsted, liquid storax, redgum, sapgum, star leaf gum, storax tree, styrax.

DESCRIPTION: A tree that grows to 140 feet in height. Corky ridges are often found on smaller branches. Leaves are star-shaped, with 5 lobes. Fruit is in woody globular capsules. Produces winged seeds.

FLOWERING PERIOD: March to May.

HABITAT: Swampy woods, alluvial areas, and moist soils.

HARVEST: Bark; gum from wounds in the trunk.

USES: This tree is an important source of the drug storax, a stimulating expectorant, weak antiseptic, desharpener for tobacco and for treating scabies. Water- or brandy-soaked twigs are chewed to clean the teeth in some areas of Appalachia.

LIQUIDAMBAR STYRACIFLUA L.

(HAMAMELIDACEAE)

LOBELIA INFLATA L.

(CAMPANULACEAE)

COMMON NAMES: Indian tobacco, asthma weed, bladder pod, bladder-podded lobelia, emetic herb, emetic weed, eyebright, field lobelia, gagroot, Indian Tobacco lobelia, lobelia, obelia, pukeweed, tobacco lobelia, vomitwort, wild tobacco.

DESCRIPTION: A branching annual that grows to 3 feet in height. Leaves are 1 to 3 inches long. Produces small, violet-pinkish-white flowers situated in axils of alternate leaves, the bottom of which greatly inflate in fruiting stage.

FLOWERING PERIOD: July to September.

HABITAT: Weedy fields, roadsides, woods, and in partial shade.

HARVEST: Herb when in flower and forming seeds.

USES: The herb yields lobeline sulfate, which is used in anti-tobacco therapy. It is also used as a stimulant, antiasthmatic, and expectorant in cases of bronchitis.

LOBELIA INFLATA L.

(CAMPANULACEAE)

LYCOPUS VIRGINICUS L.

(LAMIACEAE)

COMMON NAMES: Virginia bugleweed, bugleweed, buglewort, carpenter's herb, gypsyweed, gypsywort, horehound, Paul's betony, purple archangel, sweet bugleweed, water bugle, water horehound, wolf foot, wood betony.

DESCRIPTION: A shrub with a 4-angled stem. Dark green or purple-tinged leaves are somewhat ovate, coarsely toothed, and narrowed at each end. Whorls of tubular flowers are borne in the leaf axils.

FLOWERING PERIOD: July to October.

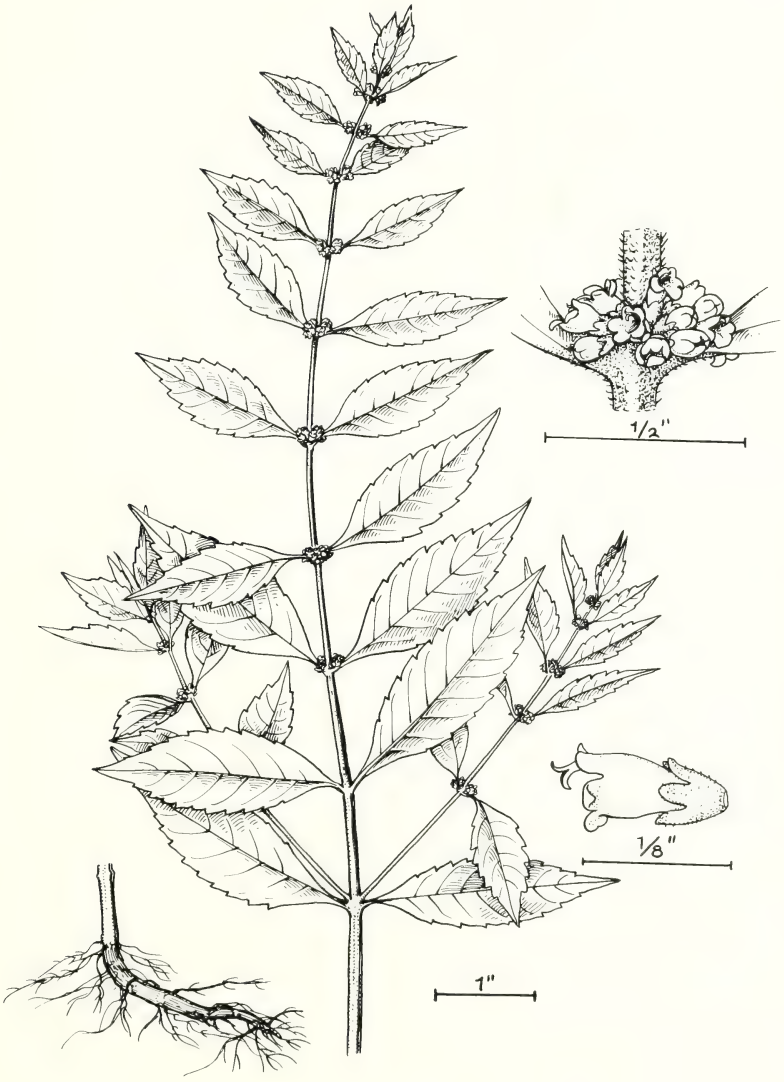
HABITAT: Rich, moist soil, in fields or forests.

HARVEST: Herb during flowering time.

USES: This herb is used as an astringent and sedative, and reportedly it has many other drug uses.

LYCOPUS VIRGINICUS L.

(LAMIACEAE)



MARRUBIUM VULGARE L.

(LAMIACEAE)

COMMON NAMES: White horehound, common hoarhound, common horehound, hoarhound, horehound, houndsbane, marrhue, marrub, marrubium, marvel, white hoarhound.

DESCRIPTION: A shrub that grows to 3 feet in height. Plant branches from base. Produces 2-inch, bitter, aromatic, round-ovate leaves that are whitish above and gray woolly below.

FLOWERING PERIOD: May to September.

HABITAT: Waste places, pastures, and old fields.

HARVEST: Leaves and small stems in May before blooming.

USES: This plant is used in many pulmonary ailments as an expectorant, tonic, and emmenagogue. In Appalachia, the leaves are used to make a cough syrup. In Europe, it is considered a febrifuge and has been used to treat menstrual pain.

MARRUBIUM VULGARE L.

(LAMIACEAE)

MENISPERMUM CANADENSE L.

(MENISPERMACEAE)

COMMON NAMES: Common moonseed, Canada moonseed, maple vine, moonseed, Texas sarsaparilla, vine maple, yellow parilla, yellow sarsaparilla.

DESCRIPTION: A woody, twining perennial vine that grows from a thick root. Leaves are wide with 3 to 7 angles or lobes around the outside margin. Produces bunches of white or greenish flowers and small black grape-like berries.

FLOWERING PERIOD: June to August.

HABITAT: Thickets and light woodlands where there is rich soil; alluvial soils, rocky ravines, fence rows, and cool regions.

HARVEST: Rhizomes and roots during fall.

USES: The root has been used as a diuretic and a stomachic. Some also claim it has value in arthritic conditions and blood disorders.

MENISPERMUM CANADENSE L.

(MENISPERMACEAE)

MENTHA PIPERITA L.

(LAMIACEAE)

COMMON NAMES: Peppermint, brandy mint, lamb mint, lammint.

DESCRIPTION: A perennial that grows to 3 feet in height. It has a pungent mint smell, and dark green, serrated leaves. Produces purplish flowers in spike-like groups in axils and terminally.

FLOWERING PERIOD: Late June to October.

HABITAT: Brook banks, wet meadows, and other damp places.

HARVEST: Herb during early flowering time.

USES: The herb is a source of the volatile oil of peppermint. Cultivated plants are grown for this product, mostly in the Pacific Northwest coast area. In Appalachia, the herb has been used generally as a flavoring agent and in treating colic and indigestion. In Europe, it is considered a carminative and is believed to increase bile secretion.

MENTHA PIPERITA L.

(LAMIACEAE)

MENTHA SPICATA L.

(LAMIACEAE)

COMMON NAMES: Spearmint, brown mint, common mint, garden mint, lady's mint, sage of Bethlehem, Scotch mint, Scotch spearmint.

DESCRIPTION: A perennial that grows to 3 feet in height. It looks like other mints but is different in odor and taste from the others. It is less pungent than *M. piperita*, and not as cooling as peppermint. Leaves are oblong, lanceolate, toothed, and about 2 inches long. Flowers are in long spikes in the upper axils and terminally.

FLOWERING PERIOD: June to October.

HABITAT: Wet places near settlements.

HARVEST: Flowering top and leaves.

USES: The herb is of value as a flavoring agent, carminative, antiemetic, refrigerant; and it is used to treat colic.

MENTHA SPICATA L.

(LAMIACEAE)

MITCHELLA REPENS L.

(RUBIACEAE)

COMMON NAMES: Partridgeberry, checkerberry, creep-chequer berry, deer berry, hive vine, one berry, running box, squawberry, squaw vine, twinberry, two-eyed berry, two-eyed chequer berry, winter clover.

DESCRIPTION: This creeping, perennial vine is distinguished by small roundish evergreen leaves that are shiny above and frequently have white lines. Produces scented white flowers tinged with purple, and scarlet, 2-eyed berries.

FLOWERING PERIOD: May to July.

HABITAT: Damp, moist, deciduous woods; often found associated with hemlock and rhododendron.

HARVEST: Herb in fall.

USES: This plant has been used frequently in ornamental terraria. The bright, orange-red berry and dark green leaves are very attractive. Therapeutically, the plant has been described as astringent, diuretic, and topic.

MITCHELLA REPENS L.

(RUBIACEAE)

MONARDA DIDYMA L.

(LABIATAE)

COMMON NAMES: Oswego beebalm, American bee balm, bee balm, bergamot, horsemint, Indian's plume, low balm, mountain balm, mountain mint, Oswego tea, red balm, rose balm, scarlet balm.

DESCRIPTION: Stems sharply four-angled, to about 4 feet in height, aromatic, simple branches to 6 inches long; leaves ovate to lance-like, toothed, rounded at base, petioled, hairy, serrate, 5 to 6 inches long; bright crimson flowers to 2 inches long in large terminal clusters at top of plant; perennial.

FLOWERING PERIOD: July to September.

HABITAT: Rich woods, thickets, bottomlands, and stream banks.

HARVEST: Herb when flowering.

USES: This herb is described as being a rubefacient, stimulant and carminative. The U. S. Dispensatory lists it as being anthelmintic. This plant is a commercial source of the drug Thymol, which is of value as an antiseptic and flavor.

MONARDA DIDYMA L.

(LABIATAE)

MYRICA CERIFERA L.

(MYRICACEAE)

COMMON NAMES: Southern wax myrtle, American vegetable tallow, American vegetable wax, bayberry, bayberry tallow, bayberry waxtree, bearing myrica, candleberry, candleberry myrtle, myrtle, southern bayberry, tallow shrub, waxberry, wax myrtle.

DESCRIPTION: A perennial shrub or small tree that grows to 35 feet in height, with waxy rough branchlets. The narrow evergreen leaves taper at both ends. Flowers are in form of short scaly catkins. Produces grayish berries.

FLOWERING PERIOD: April to June.

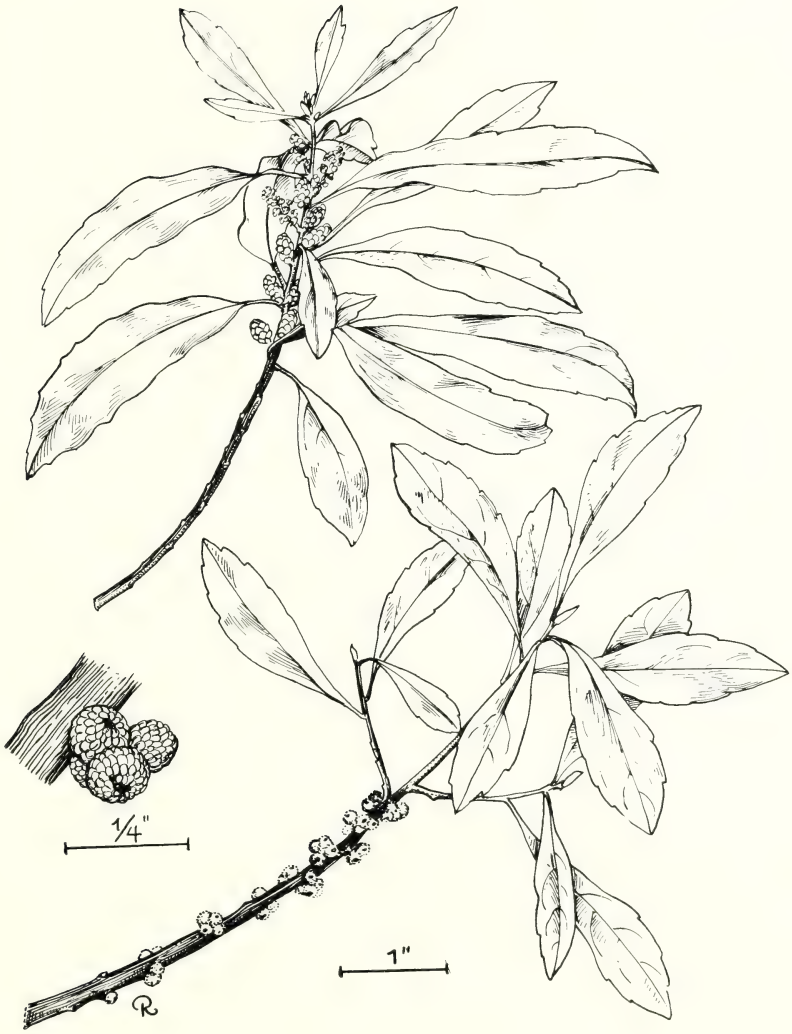
HABITAT: Poor, dry areas particularly; pine barrens and low woods.

HARVEST: Root bark in fall; roots are gently heated and bark stripped.

USES: The fruit is the main source of wax used in making candles. The root bark is astringent and emetic.

MYRICA CERIFERA L.

(MYRICACEAE)



NASTURTIUM OFFICINALE, R. BR.*

(BRASSICACEAE)

COMMON NAMES: Watercress, nasturtium, true watercress.

DESCRIPTION: A floating perennial. The large stems are freely rooting, thick, and hollow. Leaves are alternate and pinnately divided. Leaflets are entire.

FLOWERING PERIOD: April to October.

HABITAT: In thick beds in cold, flowing water of ditches, small rills, slow streams, brooks, and ponds.

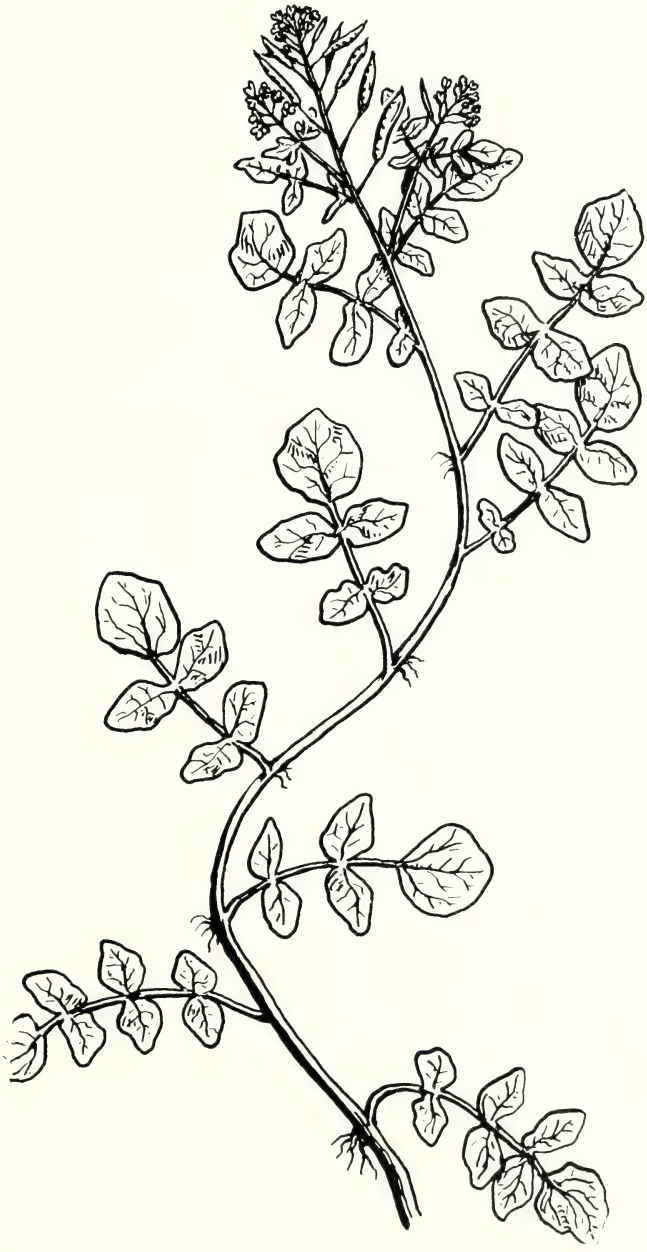
HARVEST: Herb, at any time.

USES: This floating herb is widely used as a fresh edible green. The leaves are very rich in vitamins A and C. Spanish-speaking people in New Mexico eat the plant as a treatment for kidney and heart trouble, and use it crushed in cold water as a treatment for tuberculosis. In Europe it is used to increase urine flow and to combat rheumatism and bronchitis. Pregnant women are warned not to use it because it may cause abortion.

*Synonym—*Radicula nasturtium-aquaticum* (L) Britten & Rendle.

NASTURTIUM OFFICINALE, R. BR.*

(BRASSICACEAE)



NEPETA CATARIA L.

(LAMIACEAE)

COMMON NAMES: Catnip, catmint, catnep, catrup, catwort, field balm, nip.

DESCRIPTION: An erect perennial that grows to 3 feet in height. Stem is whitish and downy. Leaves are heart-shaped, opposite, with long petioles, coarsely toothed, and about 2 to 3 inches long. The tubular flowers are ¼ to ½ inch long, whitish with purple dots, and crowded toward the tips of the stems in dense spikes.

FLOWERING PERIOD: June to September.

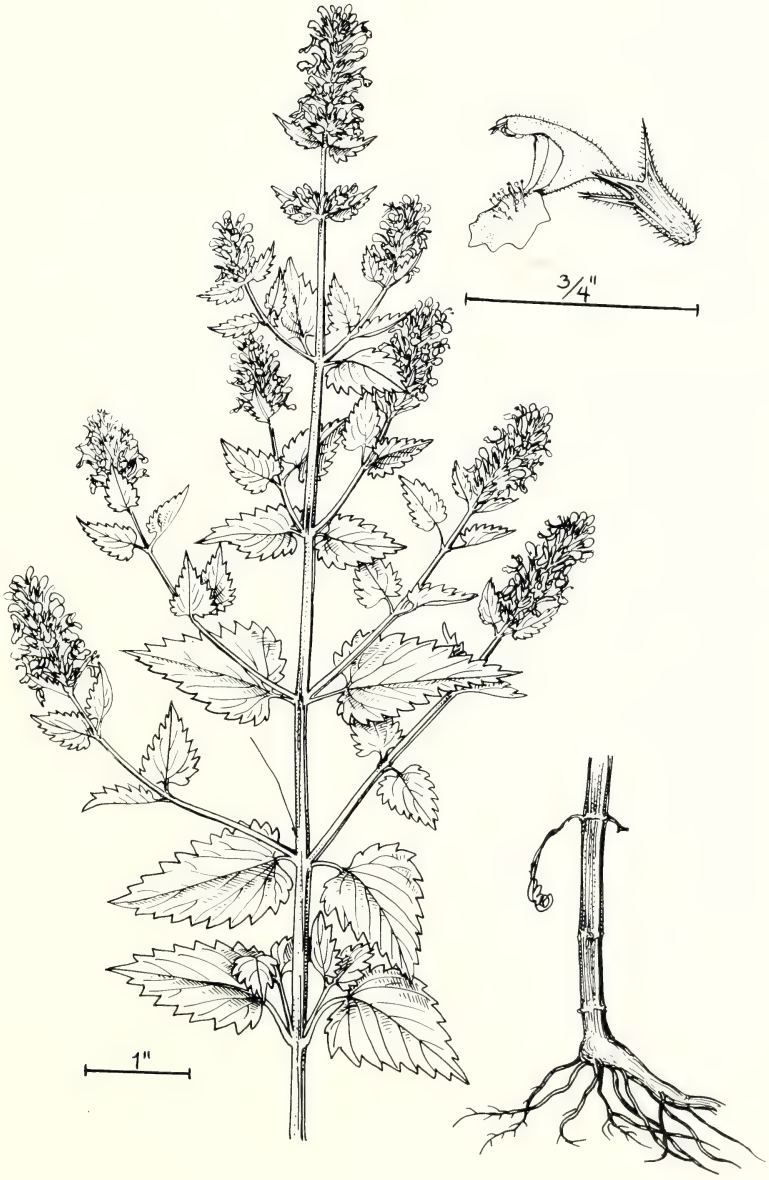
HABITAT: Dooryards, roadsides, and waste places.

HARVEST: Leafy flowering tops; herb when in full flower.

USES: As a therapeutic agent, it is used as an aromatic, stimulant, and carminative, particularly for infants. It has been used in cough remedies, and as an emmenagogue and refrigerant. The stimulating action of this plant upon cats is well known. In Appalachia, a tea made from the plant is used for treating colds, nervous conditions, stomach ailments, and hives; dried leaves and stalks are smoked for catarrh. In Europe it is used to bring on delayed menstruation.

NEPETA CATARIA L.

(LAMIACEAE)



PANAX QUINQUEFOLIUM L.

(ARALIACEAE)

COMMON NAMES: American ginseng, dwarf groundnut, five fingers, garantogen, garentoquere, gensang, ginseng, grantogen, jinshard, man's health, manroot, ninsin, redberry, sang, tartar root.

DESCRIPTION: A perennial about 6 to 8 inches long, with 2 to 4 leaves that are divided into 5 leaflets arranged palmately at the end of each leaf stalk. The small terminal stalk produces inconspicuous flowers and red berries. Roots are large and aromatic.

FLOWERING PERIOD: August.

HABITAT: Rich and cool woods.

HARVEST: Roots at 3 to 5 years, in the fall.

USES: The therapeutic value of this plant has never been established in this country, yet this is one of the most valuable woodland crops in Appalachia. The cleaned dried roots are used in the Orient as a cure-all. Because ginseng roots branch to resemble the human body, they are revered and used as a medication for any ill. In China, the roots are used in the preparations of love potions and talismans. The largest amount harvested in Appalachia is shipped to Hong Kong, Singapore, and other areas where there are large Chinese colonies. Soviet Union scientists claim to have isolated various compounds that have therapeutic value. In Appalachia, a tea made of the root is used as a tonic and aphrodisiac.

PANAX QUINQUEFOLIUM L.

(ARALIACEAE)

PASSIFLORA INCARNATA L.

(PASSIFLORACEAE)

COMMON NAMES: Maypop passionflower, apricot vine, maypop, maypop herb, passionflower, passion vine.

DESCRIPTION: A vine that grows to 25 feet in height. Leaves are alternate, composed of 3—or rarely 5—finely toothed oval lobes. Flowers are large, flesh-colored, 2 inches across, with pink or purple corona. The fruit, which is 2 to 3 inches long, is smooth, yellow, and ovate.

FLOWERING PERIOD: May to July.

HABITAT: Thickets, fence lines, edge of woods, and wastelands.

HARVEST: Herbs, leaves, roots, flowering tops, and fruit during summer.

USES: This plant has been used as an antispasmodic, sedative, and a treatment for neuralgia and epilepsy. Also, the drug has been used to reduce blood pressure and to increase the rate of respiration. It is also reputed to be an aphrodisiac, particularly for elderly men. In Bermuda, the vine is used as a perfume base.

PASSIFLORA INCARNATA L.

(PASSIFLORACEAE)

PHYTOLACCA AMERICANA L.

(PHYTOLACCACEAE)

COMMON NAMES: Pokeweed, American nightshade, cancer jalap, cancerroot, chongras, coakum, cocum, cokan, common pokeberry, crowberry, garget, inkberry, jalap, pigeonberry, pocan, pocan bush, poke, pokeberry, pokeroot, red-ink plant, red wood, scoke, skoke, Virginia poke.

DESCRIPTION: A perennial that grows to 9 feet in height. It has a thick, hollow, red stem, and an unpleasant smell. Leaves are ovate, entire, long, and petioled. Flowers are white to pinkish in terminal racemes. Produces spikes or racemes of dark purple berries.

FLOWERING PERIOD: July to September.

HABITAT: Rich, low ground, old fields, and recently cleared areas and roadsides.

HARVEST: Root in fall; ripe berries.

USES: Young shoots, when properly prepared in spring, are edible. Consumption of the plant is dangerous because it becomes poisonous as it matures. Medically it is a slow emetic and a purgative, with some narcotic properties. The dried root is reported valuable in treating hemorrhoids. In Appalachia, pokeberry wine is thought to help alleviate rheumatism; and in some areas dried fruits are used as a poultice on sores.

PHYTOLACCA AMERICANA L.

(PHYTOLACCACEAE)

PINUS PALUSTRIS MILL.

(PINACEAE)

COMMON NAMES: Longleaf pine, fat pine, Georgia pine, hard pine, heart pine, longleaf yellow pine, longstraw pine, pitch pine, rosemary pine, southern pine, southern yellow pine, turpentine pine, yellow pine.

DESCRIPTION: A large evergreen tree that grows to 80 to 120 feet in height, with coarse, scaly bark. Needles are a distinctive characteristic; they are about 8 to 18 inches long, and in groups of 3. Cones are 6 to 10 inches long, and somewhat cylindrical. Young form of tree is columnar, unbranched, and has very leafy trunk.

FLOWERING PERIOD: March to April.

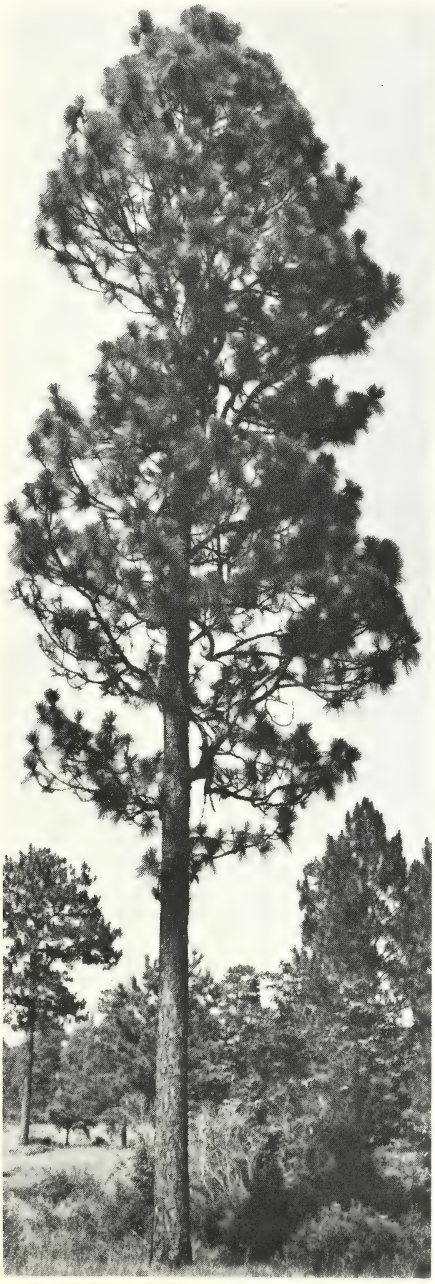
HABITAT: Sandy soil.

HARVEST: Sap in early April, and gum about last of April or first of May.

USES: This pine in southern Appalachia is a valuable source of turpentine, pine oil, tar, pitch, and rosin. The uses of turpentine oil as a rubefacient are well known. Rosin is widely used by athletes to protect their hands, and by violinists to prevent the bow from slipping and to produce better vibration. Pine tar from this source is used therapeutically for the same purpose as white pine tar. Pitch is of great value to the naval stores industry.

PINUS PALUSTRIS MILL.

(PINACEAE)



PINUS STROBUS L.

(PINACEAE)

COMMON NAMES: Eastern white pine, American deal pine, American white pine, New England pine, northern pine, northern white pine, soft deal-pine, soft pine, spruce pine, weymouth pine, white pine.

DESCRIPTION: An evergreen tree that sometimes grows to 200 feet in height. The soft bluish needles, which are 3 to 5 inches long and found in groups of 5, distinguish it from other pines. The cones are 4 to 8 inches long, thin, cigar-shaped, and often curved.

FLOWERING PERIOD: April to June.

HABITAT: Woods, old fields.

HARVEST: Inner bark, rossed or natural.

USES: The bark is used as an astringent and expectorant; the wood has been used to produce white pine tar, which has value as an antiseptic, expectorant, and protective.

PINUS STROBUS L.

(PINACEAE)

PLANTAGO L. SPP.

(PLANTAGINACEAE)

COMMON NAMES: Plantain, black psyllium, blond psyllium, fleaseed, French psyllium, Indian plantago, plantago, psyllium, psyllium seed, ribgrass, ribwort, Spanish psyllium.

DESCRIPTION: A low, weedy perennial, with broadly elliptical to linear, prominently ribbed leaves. Flowers grow tightly at apex on erect spikes.

FLOWERING PERIOD: March to October.

HABITAT: Roadsides, dooryards, lawns, poor soils, fields, and woods.

HARVEST: Seeds and leaves.

USES: The seeds are valuable as a bulk laxative. Soaking the seed in water causes it to exude a clear sticky gum, which has been used in manufacturing lotions and hair-wave sets. Some authorities report that the leaves are used as a vulnerary. In Appalachia, wet leaves of the plant are used as a poultice for snakebite and wounds; crushed fresh leaves are rubbed on wounds and skin eruptions, and are used for treating rectal itch. In Appalachia the leaves are used to make a tonic tea.

PLANTAGO L. SPP.

(PLANTAGINACEAE)

PODOPHYLLUM PELTATUM L.

(BERBERIDACEAE)

COMMON NAMES: Common mayapple, devil's apple, duck's foot, ground lemon, hog apple, Indian apple, mandrake, mayapple, podophyllum, racoonberry, umbrella plant, vegetable calomel, vegetable mercury, wild jalap, wild lemon, wild mandrake, yellowberry.

DESCRIPTION: An erect perennial that grows to about 1 to 1½ feet in height. Two umbrella-like, palmately lobed leaves grow at the top of each plant, rarely 3. The plant produces a white flower in fork of leaves, and ovate yellow fruit.

FLOWERING PERIOD: March to May.

HABITAT: Deciduous forests in mountain areas, rich woods, thickets, and pastures; prefers shade.

HARVEST: Rootstock in fall and sometimes in spring before leaves appear.

USES: Improper use of this plant could be very dangerous. The roots and rhizomes are used as a purgative. A resin from the plant, called padophyllin, has been used to treat venereal warts. The resin is extremely allergenic; it exhibits anti-tumor activity. In Appalachia, a tea of bark and roots is used to treat constipation.

PODOPHYLLUM PELTATUM L.

(BERBERIDACEAE)

POLYGALA SENEGA L.

(POLYGALACEAE)

COMMON NAMES: Seneca-snakeroot polygala, milkwort, mountain flax, rattlesnake root, senecaroot, seneca snakeroot, senega root, senega snakeroot, seneka snakeroot.

DESCRIPTION: A perennial that grows to 2 feet in height. Several stems arise from crown, and have numerous alternate linear-shaped leaves. Dense spikes of white or pinkish flowers tinged with green terminate the stem. Produces seeds in capsules.

FLOWERING PERIOD: April to July.

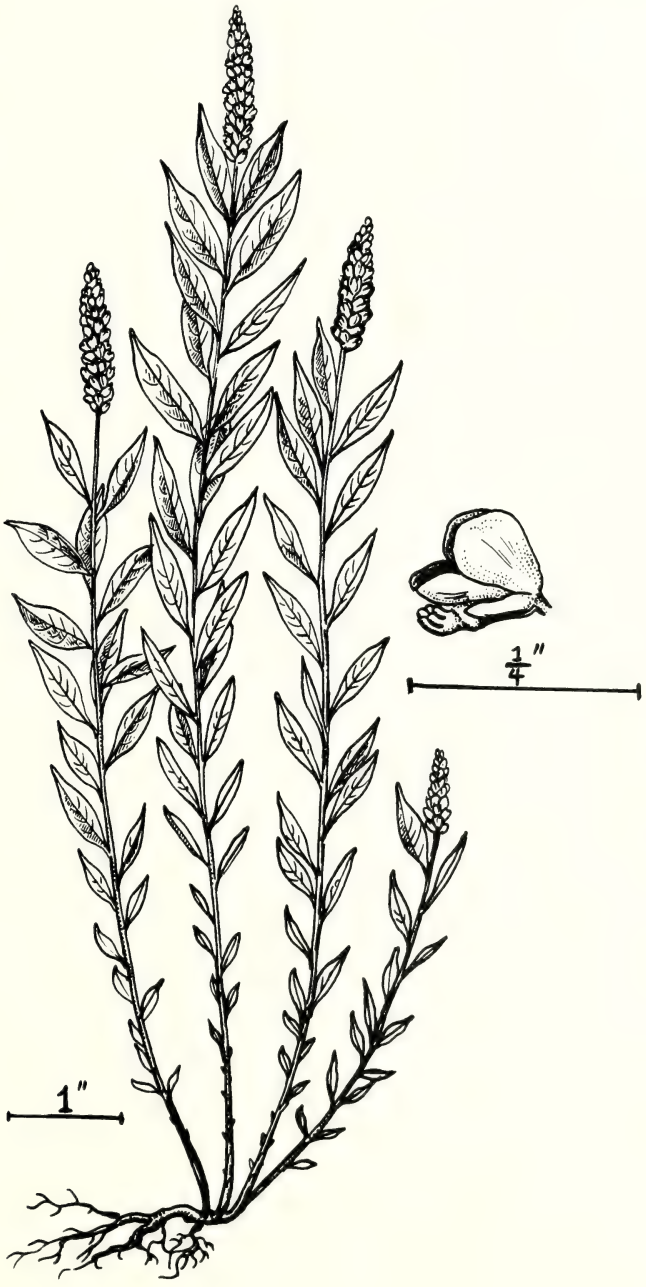
HABITAT: Dry woods on limestone, rocky soils, and higher altitudes.

HARVEST: Root in autumn. (Knotty crown must be removed first.)

USES: The plant is reportedly used as an emetic, purgative, diuretic, expectorant, and tonic.

POLYGALA SENEGA L.

(POLYGALACEAE)



POLYGONATUM BIFLORUM (WALT.) ELL.

(LILIACEAE)

COMMON NAMES: Small solomonseal, conquer-John, dwarf solomon's seal, hairy solomon's seal, sealwort, solomon's seal.

DESCRIPTION: A perennial that grows to 3 feet in height. It can be distinguished from *Smilacina racemosa* by the 1 to 4 flowers that hang from the axils of the leaves, which are about 4 inches long, 2 inches wide, and hairy below. Berries are globular, black or blue.

FLOWERING PERIOD: April to May.

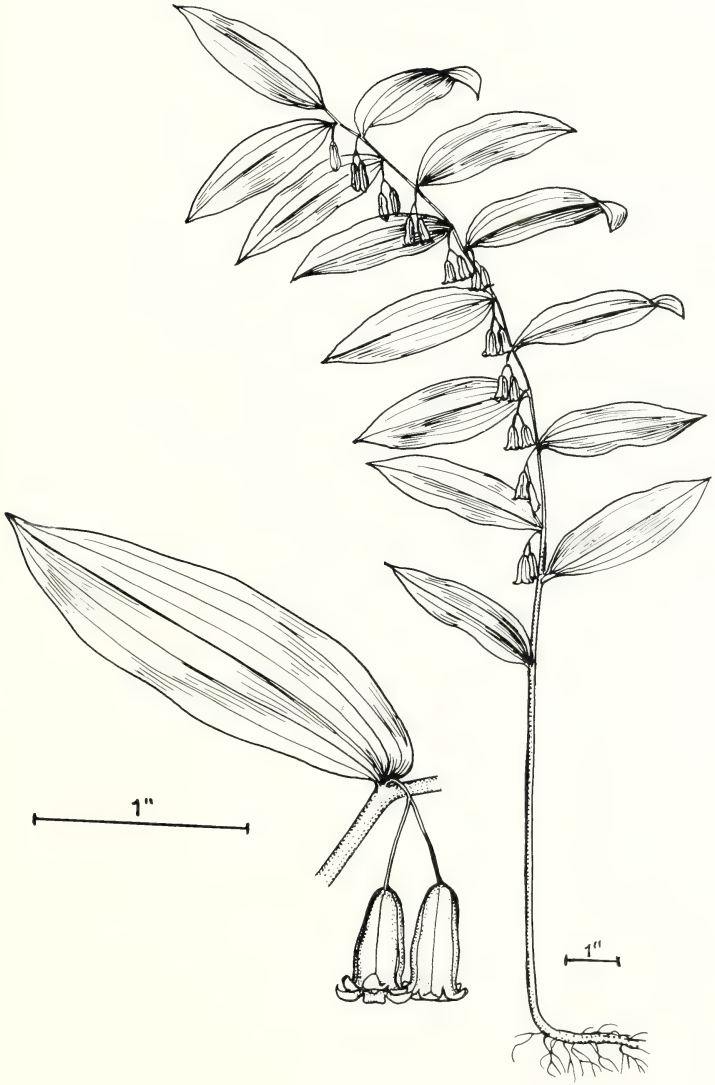
HABITAT: Dry to moist, sandy, loamy areas, or in rocky woods.

HARVEST: Root in fall.

USES: Roots and rhizomes are mildly astringent, diuretic, emetic, and tonic.

POLYGONATUM BIFLORUM (WALT.) ELL.

(LILIACEAE)



POLYGONUM HYDROPIPER L.

(POLYGONACEAE)

COMMON NAMES: Marshpepper smartweed, arsmart, biting knotweed, biting parsicaria, biting tongue, common smartweed, doorweed, lakeweed, pepperplant, red knees, red shanks, red sharks, sickleweed, smartweed, water pepper, water smartweed.

DESCRIPTION: An annual that grows to 1 to 2 feet in height. It is erect and branched at base. Stems are reddish; and leaves are narrowly lanceolate and alternate, with smooth margins 1 to 4 inches long. Produces numerous small greenish flowers that are formed close together on the ends of nodding terminal spikes.

FLOWERING PERIOD: July to October.

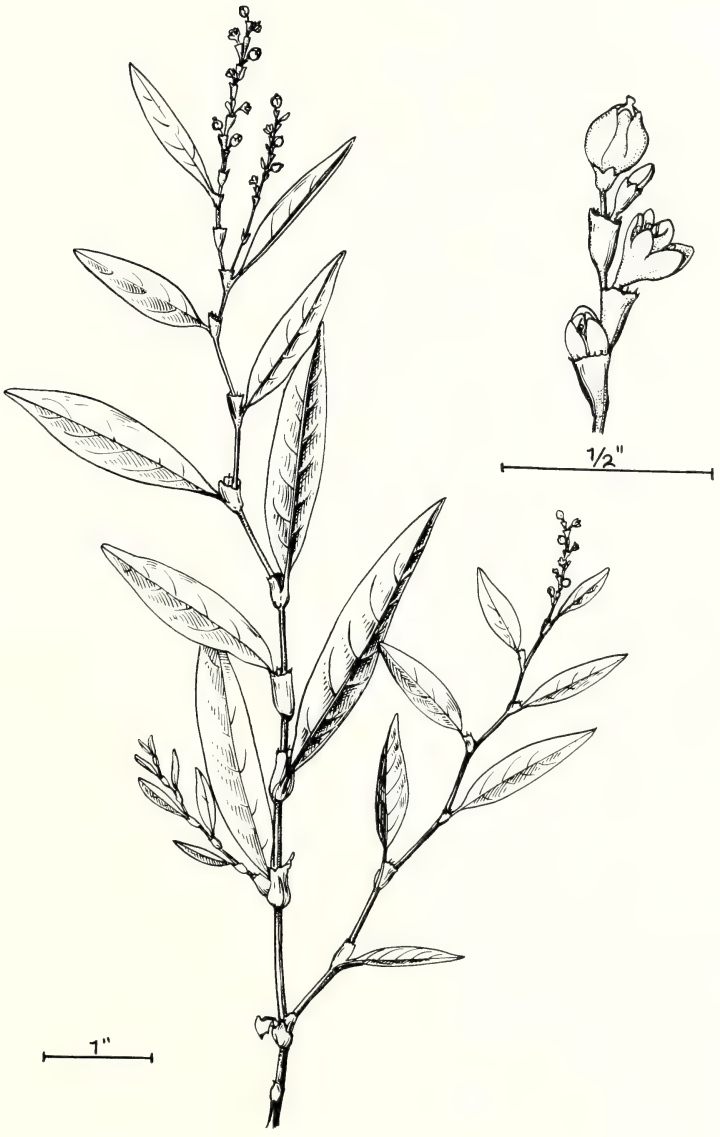
HABITAT: Damp soil.

HARVEST: Herb.

USES: The herb is a diuretic and has been used in certain uterine disorders. In Europe it is used as a hemostatic drug to control internal and hemorrhoidal bleeding.

POLYGONUM HYDROPIPER L.

(POLYGONACEAE)



POPULUS BALSAMIFERA L.

(SALICACEAE)

COMMON NAMES: Balsam poplar, balm buds, balm of Gilead, Carolina poplar, cottonwood, hackmatack, poplar balsam, tacamahac poplar, tackamahac.

DESCRIPTION: A tree that may reach 100 feet in height; sometimes the trunk is 6 feet in diameter. The broad, pointed leaves are 3 to 6 inches long and 2 to 4 inches wide; they are rounded or slightly heart-shaped at the base, finely toothed, shiny dark green above, pale green often with rusty brown patches below. The buds and twigs are brownish red, and the large buds are very resinous and fragrant.

FLOWERING PERIOD: March to April.

HABITAT: River banks, swamps, wastelands, and river bottoms.

HARVEST: Winter buds in February and March before opening.

USES: A tincture of the bark has reportedly been used to treat infections of the chest, kidneys, stomach, and for rheumatism, gout, and scurvy. The buds have been used as a vulnerary and pectoral. In Europe the fresh flowers are steeped in cold water, then strained and drunk to purify the blood.

POPULUS BALSAMIFERA L.

(SALICACEAE)

PRUNELLA VULGARIS L.

(LAMIACEAE)

COMMON NAMES: Heal-all, blue curls, brownwort, carpenter's herb, carpenterweed, common selfheal, dragonhead, hookweed, self-heal, sickleweed, sicklewort.

DESCRIPTION: A perennial that grows to 2 feet in height. Usually the plant is much tufted, and sometimes it is horizontal. Leaves are round and bract-like. Violet purple blooms, about 1/2 inch long, are found in the axils of the leaves, in a close spike or head.

FLOWERING PERIOD: April to October.

HABITAT: Roadsides, lawns, fields, pastures, wastelands, and grasslands.

HARVEST: Herb from May to September, at flowering time.

USES: The herb is used as an aromatic and carminative. It has been used also as a gargle, and in treating hemorrhage and diarrhea.

PRUNELLA VULGARIS L.

(LAMIACEAE)

PRUNUS SEROTINA EHRH.

(ROSACEAE)

COMMON NAMES: Black cherry, black choke, cabinet cherry, choke cherry, mountain black cherry, rum cherry, Virginia prune bark, whicky cherry, wild black cherry, wild cherry.

DESCRIPTIONS: A valuable tree that grows to 100 feet in height and has a straight trunk covered with rough, black bark. Inner bark is aromatic. The young branches are smooth and reddish. Leaves are shiny, smooth, and finely toothed, 2 to 5 inches long. Small white flowers occur in long drooping clusters at the end of the branches, followed by clusters of round, black berries that are edible but bitter.

FLOWERING PERIOD: April to May.

HABITAT: Along fence rows, roadsides, streamsides, pastures, and in dry woods.

HARVEST: Young, thin bark; and bark from older trees after it has been rossed; also, fruit when ripe.

USES: The bark is used primarily as a flavoring agent. The drug is an excellent expectorant. Appalachian wild cherry bark tea is used for coughs, colds, and cholera.

PRUNUS SEROTINA EHRH.

(ROSACEAE)

QUERCUS ALBA L.

(FAGACEAE)

COMMON NAMES: White oak, common white oak, fork-leaf white oak, ridge white oak, stave oak, stone oak, tanner's oak.

DESCRIPTION: A tree that is usually 60 to 80 feet in height, but sometimes reaches 150 feet. The bark is a light ashy gray, variable in appearance—from loosely attached plates on young trees to narrow, rounded ridges with deep fissures on old trees. The smooth thin leaves, which are 5 to 9 inches long, have short stems and are usually divided into 7 to 9 smooth, rounded lobes.

FLOWERING PERIOD: March to May.

HABITAT: Widely distributed in hardwood forests of the eastern United States.

HARVEST: Inner bark, at any time; bark from older trees should be collected in spring.

USES: The pollen is reportedly allergenic. Because the bark contains tannins, it is used as an astringent and antiseptic. In Appalachia, a bark tea is used to treat burns and sore mouth. A chartreuse dye is obtained from the bark.

QUERCUS ALBA L.

(FAGACEAE)

RHUS GLABRA L.

(ANACARDIACEAE)

COMMON NAMES: Smooth sumach, common sumac, Pennsylvania sumach, scarlet sumac, shernoke, sumac, upland sumach, vinegar tree.

DESCRIPTION: A shrub or small tree that grows to about 15 feet in height. Leaves are 1 to 3 feet long, with 11 to 31 leaflets; each leaflet is 2 to 4 inches long and about 1 to 2 inches wide, pointed and sharp-toothed. Twigs are smooth. Produces greenish yellow flowers in clumps at branch ends, and roundish, flattened, bright red fruits or berries that are hairy and sticky.

FLOWERING PERIOD: May to July.

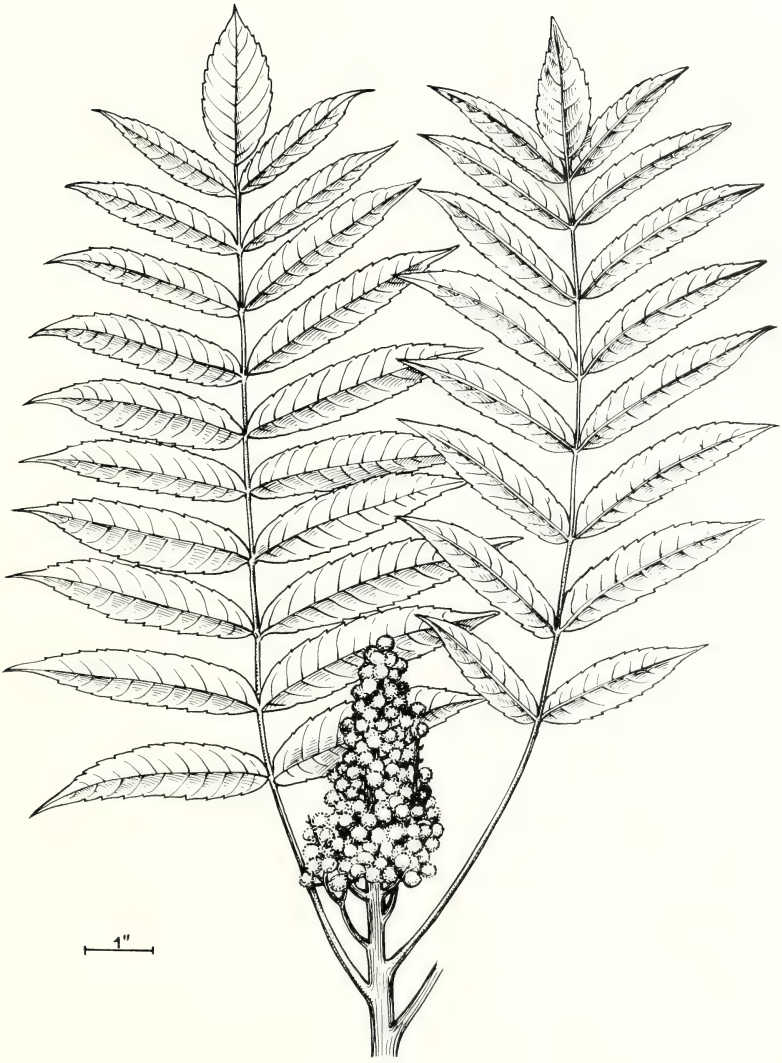
HABITAT: Old fields, power line cuts, roadsides, meadows, and pastures.

HARVEST: Bark of stem and roots, ripe fruit, and leaves.

USES: The dried ripe fruit of sumac is valuable as a source of tannic acid. Preparations of these fruits are effective as astringents, antidiuretics, and tonics. In Appalachia, leaves are smoked to treat asthma. The stems produce a yellow dye.

RHUS GLABRA L.

(ANACARDIACEAE)



RUBUS SPP. L.

(ROSACEAE)

COMMON NAMES: Blackberry, brambleberry, dewberry, raspberry.

DESCRIPTION: A prickly, shrubby or viny perennial that produces 5-petaled, white flowers. Fruit is either black or red.

FLOWERING PERIOD: May to August.

HABITAT: Old fields, waste lands, pastures, fence rows, forest borders.

HARVEST: Bark, fruit, leaves, root, and root bark.

USES: The roots and rhizomes of this plant have been used as astringents because of their high tannin content. In Appalachia, a tea made of roots is used to stop secretions. A fruit juice and wine made from the berries is used to control diarrhea. A tea made from the bark of wild raspberry is used to control dysentery.

RUBUS SPP. L.

(ROSACEAE)

RUMEX CRISPUS L.

(POLYGONACEAE)

COMMON NAMES: Curly dock, bitter dock, curled dock, dock, garden patience, narrow dock, sour dock, yellow dock.

DESCRIPTION: A perennial that grows to 5 feet in height. Leaves are 6 to 12 inches long, linear, and curly-edged. Produces yellow to green flowers in panicles, and dense spikes of winged triangular seeds.

FLOWERING PERIOD: April to August.

HABITAT: Pastures, fields, and waste lands.

HARVEST: Roots, in late summer and fall.

USES: The roots of this plant are reportedly valuable as an astringent and mild laxative. In Appalachia, the root is placed in vinegar and the wash is used to treat ringworm; the leaves are used in a poultice to treat hives. The Indians used the root for a yellow dye.

RUMEX CRISPUS L.

(POLYGONACEAE)

SALIX ALBA L.

(SALICACEAE)

COMMON NAMES: White willow, European white willow.

DESCRIPTION: A tree that grows to 80 feet in height, with spreading and drooping branches. Branchlets are often silky white when young; later they turn olive-brown. Leaves are 1 1/2 to 4 inches long, very narrow, sharp-pointed, very finely toothed, shiny green above and silky white below. Flowers occur in catkins.

FLOWERING PERIOD: April to May.

HABITAT: Stream banks, roadsides, and shaded moist areas.

HARVEST: Bark during flowering time; buds in spring.

USES: The therapeutic value of white willow buds is similar to that of *Populus* species. The bark is reportedly an expectorant, hemostatic, astringent, and tonic. In Appalachia, leaves and bark of different willows are used in a tea to break up fever.

SALIX ALBA L.

(SALICACEAE)

SALIX NIGRA MARSH.

(SALICACEAE)

COMMON NAMES: Black willow, pussy willow, swamp willow, willow.

DESCRIPTION: A tree that often grows to 40 feet in height, but may reach 100 to 120 feet. Leaves are very narrow, 3 to 6 inches long and up to 3/4 inch wide, sharp-pointed, finely toothed, short-stemmed. Twigs are slender, reddish brown, and usually brittle. Produces male and female flowers in separate catkins; male catkins are 1 to 2 inches long and the female 1 1/2 to 3 inches long.

FLOWERING PERIOD: April to June.

HABITAT: Banks of streams, lake shores, and in rich, low woods.

HARVEST: Strip bark with buds from 2- or 3-year-old branches in spring.

USES: The buds and bark are used for the same purposes as those of *S. alba*.

SALIX NIGRA MARSH.

(SALICACEAE)

SALVIA OFFICINALIS L.

(LAMIACEAE)

COMMON NAMES: Garden sage, meadow sage, sage, scarlet sage, true sage.

DESCRIPTION: A fuzzy perennial that grows to 2 1/2 feet in height. Leaves are lanceolate to narrowly elliptic, with rounded teeth, narrowing at base to long petioles. Flowers are in whorls of 4 to 8 in terminal spikes, blue or white.

FLOWERING PERIOD: July to September.

HABITAT: Dumps, waste lands, and gardens.

HARVEST: Herb at flowering time; leaves.

USES: Sage reportedly has many therapeutic uses. The drug is an astringent and carminative. In Appalachia, it was thought to serve as a laxative and a gargle; and it was used to treat baldness, loose teeth, and gas. European research suggests estrogen is present but has not been isolated. It has been used to help achieve regularity of menstrual period. However, its major use is for culinary purposes.

SALVIA OFFICINALIS L.

(LAMIACEAE)

SANGUINARIA CANADENSIS L.

(PAPAVERACEAE)

COMMON NAMES: Bloodroot, coonroot, pauson, puccoon, puccoon root, red Indian paint, red puccoon, redroot, snakebite, sweet slumber, tetterwort, turmeric, white puccoon.

DESCRIPTION: A perennial that grows to 6 to 14 inches in height, with a solitary leaf-stem. Leaves are palmately lobed around outer edge. In early sping, produces white flowers 1 to 2 inches in width. A distinctive characteristic of this plant is the red juice produced by the root.

FLOWERING PERIOD: April to May.

HABITAT: Deep, cool, moist, deciduous woodland slopes; rich woods.

HARVEST: Rootstock at time of flowering, in late summer or early fall.

USES: This plant is extremely poisonous. It is a source of morphine, and improper use should be avoided. The drug is an emetic, laxative, and emmenagogue; and because of its expectorant qualities, it has been used to treat chronic bronchitis. The plant is used both as a pain reliever and a sedative. When combined with oak bark, the roots give a red dye. In Appalachia, a piece of bloodroot is sometimes carried as a charm to ward off evil spirits.

SANGUINARIA CANADENSIS L.

(PAPAVERACEAE)

SASSAFRAS ALBIDUM (NUTT.) NEES

(LAURACEAE)

COMMON NAMES: Sassafras, ague tree, cinnamon wood, common sassafras, red sassafrass, saxifras, smelling stick, white sassafras.

DESCRIPTION: A tree that grows to 40 feet in height. Twigs are green and produce leaves of 3 different shapes: 3-lobed, 2-lobed or mitten-shaped, and unlobed. All parts of the tree have a spicy aroma. Fragrant, yellowish-green flowers are borne in clusters. Male and female flowers are usually borne on different trees. In September the female flowers develop into dark blue 1-seeded berries, about pea size, that are borne on a thick red stalk.

FLOWERING PERIOD: March to April.

HABITAT: Along fence rows; in open woods and abandoned fields, and on dry ridges.

HARVEST: Root bark in spring and autumn; entire root in fall.

USES: The root bark can be used to prepare a tea. Root material can be distilled to make sassafras oil, which is used mainly as a flavoring agent in beverages, confectionery tooth paste, and the like. The tea has been used as a diaphoretic, stimulant, diuretic, and carminative; and it is used in Appalachia to treat bronchitis. The bark is reportedly used also as an insect repellent. Colonial Americans were advised to chew the bark of this tree to break the tobacco habit. Sassafras leaves have been used as a dye to make a soft yellow tan. And some research suggests that, under certain conditions, the leaves may be carcinogenic.

SASSAFRAS ALBIDUM (NUTT.) NEES

(LAURACEAE)

SCROPHULARIA MARILANDICA L.

(SCROPHULARIACEAE)

COMMON NAMES: Maryland figwort, brownwort, bullwort, Carpenter's square, figwort, great pilewort, heal-all, Holme's weed, kernelwort, knotted root, murrian grass, pilewort, scrofula plant, square stalk, stinking Christopher.

DESCRIPTION: A perennial that grows to 9 feet in height, with 4-angled stems. Leaves are opposite, thin, 3 to 12 inches long, with toothed margins, ovate or rounded and broad at base, tapering to a point at tip. The small reddish-brown flowers are loosely arranged on irregular thin branches at the top of the plant.

FLOWERING PERIOD: June to October.

HABITAT: Rich woods and thickets, open woodlands, fallow fields, and roadsides.

HARVEST: Leaves, roots, and herb at flowering time.

USES: The herb is used as a tonic, diuretic, diaphoretic, and in reducing hemorrhoids.

SCROPHULARIA MARILANDICA L.

(SCROPHULARIACEAE)

SCUTELLARIA LATERIFLORA L.

(LAMIACEAE)

COMMON NAMES: Sideflowering skullcap, American skullcap, blue pimernel, blue skullcap, helmet flower, hooded willow herb, hoodwort, mad-dog, mad-dog skullcap, mad-dog weed, madweed, skullcap.

DESCRIPTION: An erect widely-branched perennial that grows to 30 inches in height. The stem is slender and 4-sided. Leaves are thin, 1 to 4 inches long, ovate, pointed, coarsely serrated, and opposite. The flowers are blue, 2-lipped, and arranged along spikes in each of the upper leaf axils.

FLOWERING PERIOD: July to October.

HABITAT: Alluvial thickets, meadows, swampy woods, moist areas, and shaded areas.

HARVEST: Herb in early summer.

USES: The plant has been used for treating hydrophobia, but without much success. It is reputed to be a nervine, tonic, diuretic, and antispasmodic.

SCUTELLARIA LATERIFLORA L.

(LAMIACEAE)

SENECIO AUREUS L.

(ASTERACEAE)

COMMON NAMES: Golden ragwort, butterweed, cocashweed, coughweed, false valerian, female regulator, golden groundsel, golden senecio, groundsel, liferoot, ragwort, squawweed, swamp squawweed, uncum, waxweed, wild valerian.

DESCRIPTION: A perennial that grows to 1 to 2 1/2 feet in height, with 1 to several erect flowering stems. The slender basal leaves are heart-shaped and long petioled (to 6 inches); the rest of the stem leaves are variously cleft, with lobes arranged on either side of the main mid-vein of the leaf. The spring-blooming composite flowers are yellow. The roots are characterized by horizontal creeping.

FLOWERING PERIOD: March to June.

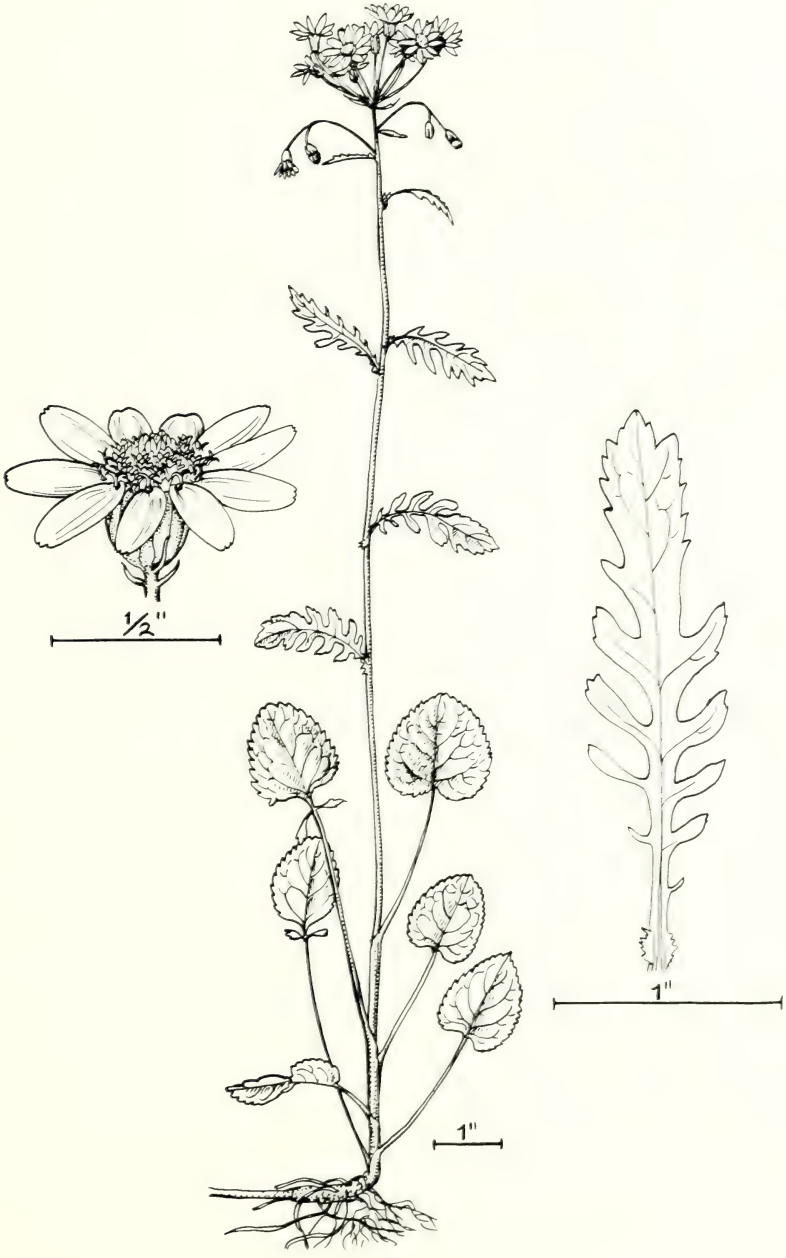
HABITAT: Rich calcareous woods and bottoms, upland swamps, and humid areas.

HARVEST: Root; herb in May when flowering; entire plant before flowering.

USES: As the common name, "coughweed", would indicate, the herb is an expectorant and pectoral. In addition to these qualities, it is listed as an emmenagogue and vulnerary.

SENECIO AUREUS L.

(ASTERACEAE)



SOLANUM CAROLINENSE L.

(SOLANACEAE)

COMMON NAMES: Horse nettle, apple of Sodom, ball nettle, bull nettle, Carolina horse nettle, nightshade, sand brier, tread-softly.

DESCRIPTION: A prickly erect perennial that grows to 3 feet in height. Leaves are shallowly lobed pinnately, broad, with yellow thorns on veins beneath. Flowers are pale violet to white. Fruit is a yellow berry.

FLOWERING PERIOD: May to September.

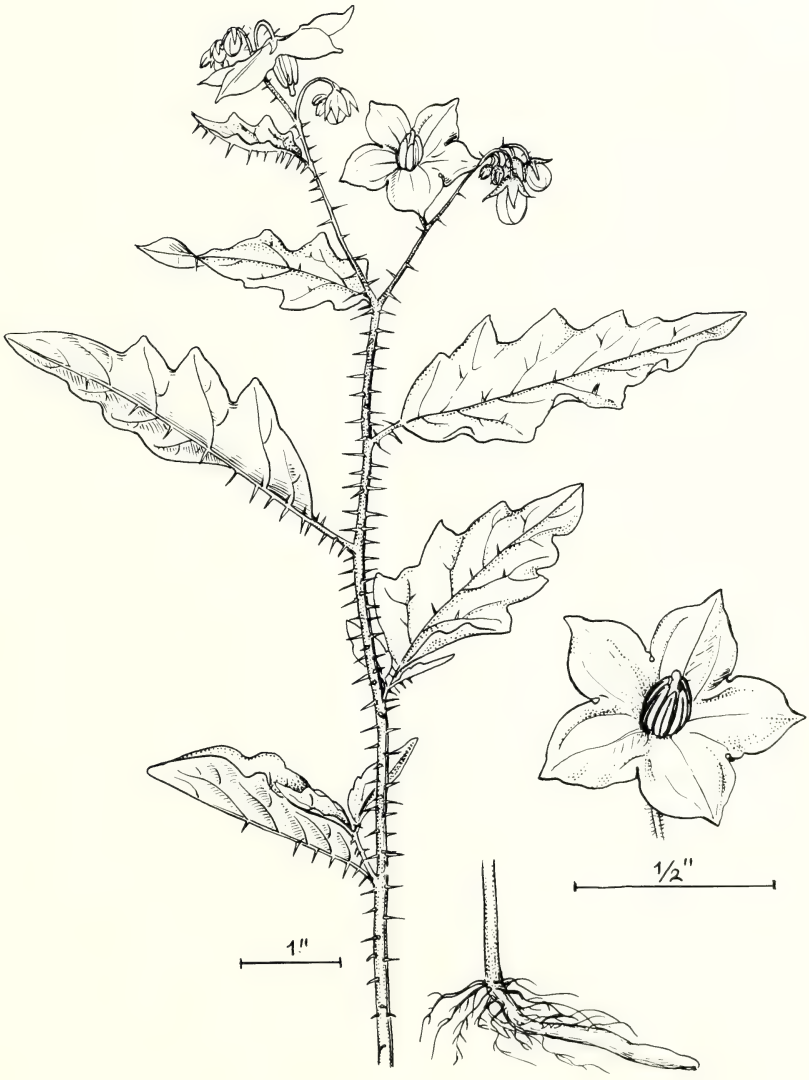
HABITAT: Sandy openings, dry fields, waste lands, and roadsides.

HARVEST: Berries, leaves, and rootstock in the fall.

USES: This plant is extremely poisonous. The berries, when properly prepared, have been used as diuretics, antispasmodics, anodynes; and according to the U. S. Dispensatory, they have also been used in a treatment for epilepsy.

SOLANUM CAROLINENSE L.

(SOLANACEAE)



*SORBUS AMERICANA** MARSH.

(ROSACEAE)

COMMON NAMES: American mountainash, American rowan tree, American service tree, dogberry, Indian mozemize, life-of-man, masse-misse, missy-massy, missey-moosey, mountain ash, mountain sumach, quick beam, round tree, roundwood, wild ashe, wine tree, witchwood.

DESCRIPTION: A shrub or small tree that grows to 30 feet in height. Bark is smooth and light gray. Compound leaves consist of 11 to 17 narrow, pointed, toothed leaflets about 1 1/4 to 4 inches long. White flowers appear in dense, round, or flatish clusters about 3 to 6 inches across. Large, dense, showy clusters of bright red berries about the size of peas appear in late fall.

FLOWERING PERIOD: June to July.

HABITAT: Evergreen forests and waste areas.

HARVEST: Bark and fruit.

USES: The berries have been used to treat scurvy and as a vemifuge. Bark preparations have been used for biliousness.

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*Synonym = *Pyrus americana* (Marsh) D.C.

*SORBUS AMERICANA** MARSH.

(ROSACEAE)

SPIGELIA MARILANDICA L.

(LOGANIACEAE)

COMMON NAMES: Pinkroot spigelia, American wormroot, Carolina pink, Carolina pinkroot, Indian pink, Maryland pinkroot, perennial wormgrass, pinkroot, snakeroot, star bloom, unstilla, wormgrass.

DESCRIPTION: A perennial that grows to 1 to 2 feet in height. Leaves are opposite, without a petiole, lanceolate to broadly oval. Flowers are funnel-like, red on the outside, yellow on the inside, arranged on one side of a single spike. The funnel forms five lobes at the open end.

FLOWERING PERIOD: May to June.

HABITAT: Rich woods.

HARVEST: Rootstock after flowering in early fall.

USES: The root is used as a vermifuge, anthelmintic, and cathartic. Some authorities say it is also a narcotic. In Appalachia, a tea made from the leaves is used to aid digestion.

SPIGELIA MARILANDICA L.

(LOGANIACEAE)

STELLARIA MEDIA (L.) CYRILLO

(CARYOPHYLLACEAE)

COMMON NAMES: Chickweed, adder's mouth, common chickweed, satin flower, starwort, stitchwort, tongue grass, white bird's eye.

DESCRIPTION: An annual that grows to 12 inches in height. The plant is weak, with matted to upright trailing stems. Lower and median leaves are ovate; upper leaves are sessile and highly variable. Solitary flowers have 4 to 5 star-shaped white petals that are 2-cleft.

FLOWERING PERIOD: January to March.

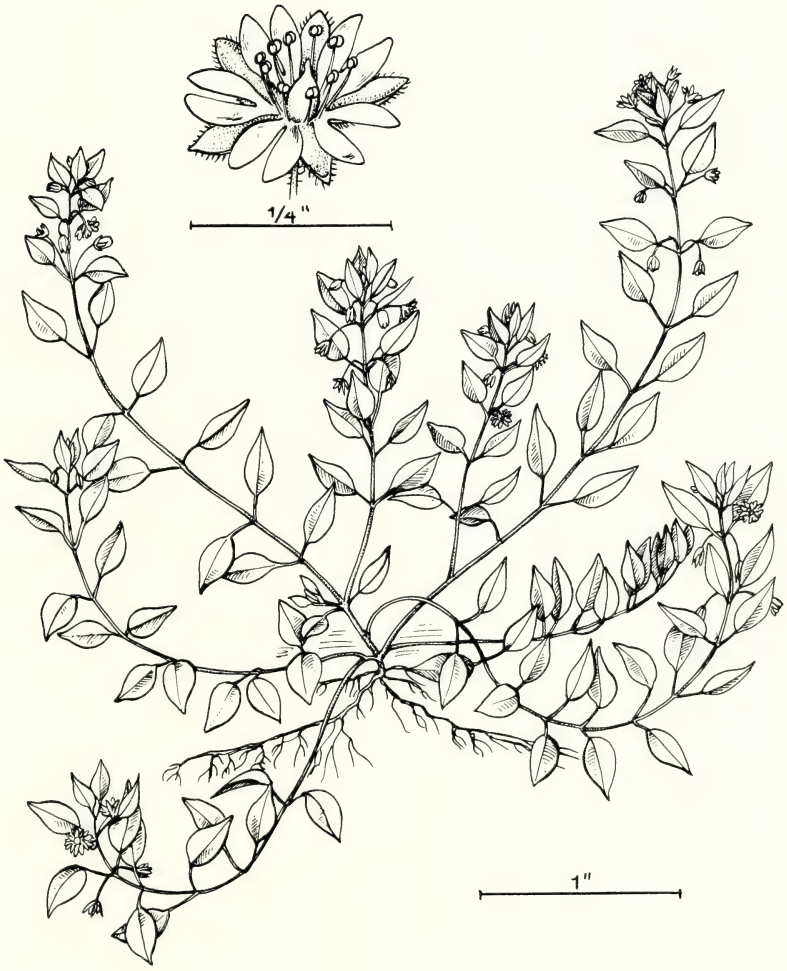
HABITAT: Found in dooryards, cultivated ground, waste land, damp woods, thickets, and gardens.

HARVEST: Herb.

USES: The herb is classed as a refrigerant, demulcent, and expectorant.

STELLARIA MEDIA (L.) CYRILLO

(CARYOPHYLLACEAE)



STILLINGIA SYLVATICA L.

(EUPHORBIACEAE)

COMMON NAMES: Queensdelight, cock-up-hat, cocyshat, marcony, nettle potato, queen's delight stillingia, queen's root, silver leaf, stillingia, yaw root.

DESCRIPTION: A perennial that grows to 3 feet in height. It is a milky-juiced plant with fleshy, crowded, leathery, stemless leaves that vary in shape: some are round, others sharply sawtoothed. Flowers are yellow.

FLOWERING PERIOD: May to July.

HABITAT: Sandy, dry soil, pine barrens, old fields, and forest openings.

HARVEST: Rootstock in August or September.

USES: The root has been classed as emetic, cathartic, and diuretic.

STILLINGIA SYLVATICA L.

(EUPHORBIACEAE)

TANACETUM VULGARE L.

(ASTERACEAE)

COMMON NAMES: Tansy, bitter buttons, common tansy, double tansy, English cost, ginger plant, golden buttons, hind heal, parsley fern, scented fern.

DESCRIPTION: A perennial 2 to 3 feet in height, with erect unbranched stems that grow in clumps. Pungent, aromatic, fern-like foliage is a common characteristic. Leaves are alternate, topped with flat heads of yellow, tubular, button-like flowers.

FLOWERING PERIOD: July to September.

HABITAT: Roadsides and borders of fields.

HARVEST: Herb.

USES: The herb has been used as an anthelmentic, emmenagogue, and stomachic. The dried flower heads are used frequently in flower arrangements.

TANACETUM VULGARE L.

(ASTERACEAE)

TEPHROSIA VIRGINIANA (L.) PERS.

(FABACEAE)

COMMON NAMES: Virginia tephrosia, catgut, devil's shoe strings, goat's rue, hoary pea, rabbit pea, turkey pea.

DESCRIPTION: A perennial that grows to 2 feet in height. Stem is erect, simple, and leafy to the top, with narrowly elliptic leaflets arranged compoundly on either side of main stem, which is hairy. Flowers are large and densely cluttered on a terminal spike; they are yellowish white marked with purple. The podlike fruits are heavy and hairy, about 2 inches long.

FLOWERING PERIOD: Mid-May to August.

HABITAT: Dry, sandy woods and openings.

HARVEST: Herb in summer; roots in fall.

USES: The root of this plant is used as an insecticide and, according to the U. S. Dispensatory, as a vermifuge.

TEPHROSIA VIRGINIANA (L.) PERS.

(FABACEAE)

TIARELLA CORDIFOLIA L.

(SAXIFRAGACEAE)

COMMON NAMES: Allegheny foamflower, coalwort, coolwort, false bitterwort, false miterwort, foam flower, gem fruit.

DESCRIPTION: A perennial that grows to 1 foot in height. The heart-shaped leaves are broad, shallowly lobed, toothed, 4 inches across. Flower petals are lanceolate, white or pinkish, and arranged on a spike-like stem.

FLOWERING PERIOD: April to July.

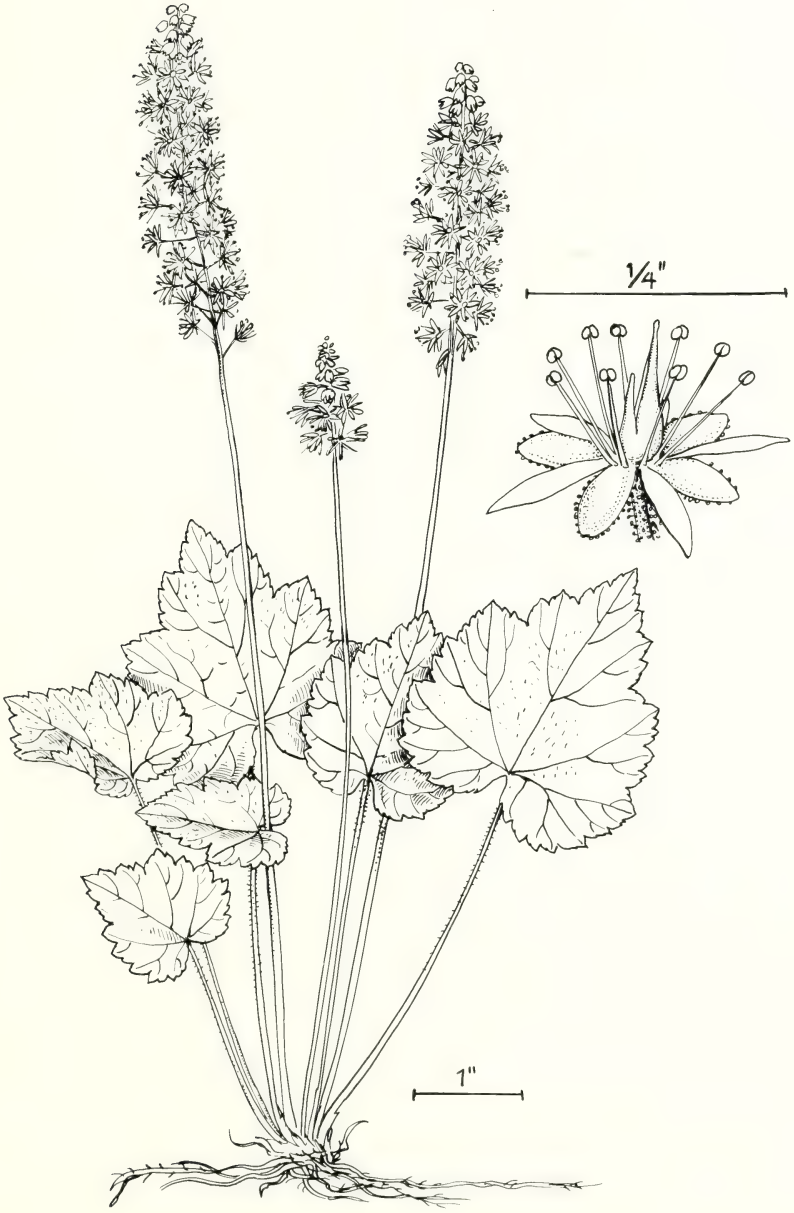
HABITAT: Rich woodlands and uplands.

HARVEST: Herb during flowering; root in fall.

USES: This herb is reputed to be useful as a tonic and diuretic. The root is classed as a diuretic and pectoral.

TIARELLA CORDIFOLIA L.

(SAXIFRAGACEAE)



TRIFOLIUM PRATENSE L.

(FABACEAE)

COMMON NAMES: Red clover, broadleaved clover, cleaver grass, common clover, common red clover, cow clover, meadow clover, purple clover, sweet clover.

DESCRIPTION: A biennial or perennial legume, with long-petioled, tri-foliolate leaves, each with 3 oval-shaped leaflets. The gobular to ovate flower heads are dense and roseate colored.

FLOWERING PERIOD: May to September.

HABITAT: Roadsides, clearings, turf, fields, and meadows.

HARVEST: Flowers and herb.

USES: The flowers of this plant are therapeutically used as an antispasmodic, expectorant, sedative, and vulnerary. The U. S. Dispensatory reports that the flowers have been used in some anti-asthma cigarettes. In central Europe, clover has been used to regulate digestive functions, to improve the appetite, and to treat liver ailments.

TRIFOLIUM PRATENSE L.

(FABACEAE)

TRILISA ODORATISSIMA (WALT.) CASS

(ASTERACEAE)

COMMON NAMES: Vanilla trilisa, deerstongue, dogtongue, vanilla leaf, vanilla plant.

DESCRIPTION: An erect, stout perennial that grows to 2 to 3 feet in height. Basal leaves are large, smooth, spatula-like, with stem-clasping leaves diminishing as they ascend the stem. Leaves are alternate, and up to 10 inches long. Foliage is vanilla-scented. Flowers are in flat-topped purplish clusters.

FLOWERING PERIOD: July to September.

HABITAT: Open, low pine forests of the Southeast, damp fields, and barrens.

HARVEST: Leaves in early summer to fall.

USES: The herb has no reported drug use. However, it is used as a blend with tobacco, and because it is high in coumarin it has been used to flavor medicinal compounds.

TRILISA ODORATISSIMA (WALT.) CASS

(ASTERACEAE)

TRILLIUM ERECTUM L.

(LILIACEAE)

COMMON NAMES: Purple trillium, bath flower, bathwort, bethroot, bettroot, birthroot, birthwort, bumblebee root, daffydown-dilly, dishcloth, ground lily, illscented trillium, illscented wakerobin, Indian balm, Indian shamrock, lamb's quarters, nosebleed, orange blossum, purple wakerobin, rattlesnake root, red Benjamin, red trillium, red wakerobin, squaw flower, squaw root, stinking Benjamin, three-leaved nightshade, trillium, true love, wakerobin, wood lily.

DESCRIPTION: A perennial that grows to 1 to 2 foot in height. It has a single stout stem with a whorl of 3 broad leaves at the top, and a single brown or greenish purple ill-scented flower growing from the center of the whorl of leaves.

FLOWERING PERIOD: April to early June.

HABITAT: Rich, damp, shady woods.

HARVEST: Root in late summer or fall.

USES: The plant has been used as an antispasmodic, emmenagogue, emetic, expectorant, and uterine astringent. The Indians of Appalachia cooked pieces of the root in food as an aphrodisiac.

TRILLIUM ERECTUM L.

(LILIACEAE)

TSUGA CANADENSIS (L.) CARR.

(PINACEAE)

COMMON NAMES: Eastern hemlock, Canada hemlock, hemlock, hemlock fir, hemlock spruce, hemlock spruce pine, spruce pine, tan-bark tree, weeping spruce.

DESCRIPTION: An evergreen tree, usually 60 to 70 feet in height. Leaves are 1/3- to 2/3-inch long, needle-like, flattened, tapering from base to tip, bright green above, light silvery green with 2 white streaks below. Cones are small, 1/2 to 3/4 inch long. Bark is dark reddish-brown, and deeply furrowed.

FLOWERING PERIOD: April to early June.

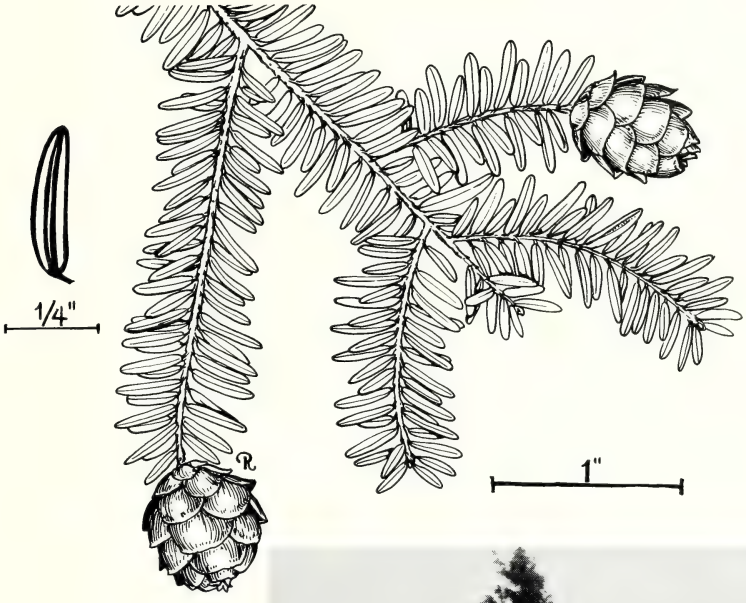
HABITAT: Hilly, mountainous, rocky woods, upland loams, moist benches, and swamp borders.

HARVEST: Bark and resin, which is collected by cutting the trunk of the tree.

USES: The bark has been used primarily because of its tannin content, which makes it a strong astringent. Resin is used as a mild rubefacient and veterinary liniment.

TSUGA CANADENSIS (L.) CARR.

(PINACEAE)



ULMUS RUBRA MUHL.

(ULMACEAE)

COMMON NAMES: Slippery elm, American tree, elm, gray elm, Indian elm, moose elm, red elm, rock elm, soft elm, sweet elm, tawny elm.

DESCRIPTION: A tree 60 to 70 feet in height, with dark green leaves 5 to 7 inches long, 2 to 3 inches wide, nearly oval-shaped, rough above and hairy beneath. Twigs are rough and ashy gray in color. Buds are dark colored and hairy. Buds at branch ends usually have orange tips. Inner bark is mucilaginous with a somewhat aromatic flavor.

FLOWERING PERIOD: Late February to early May.

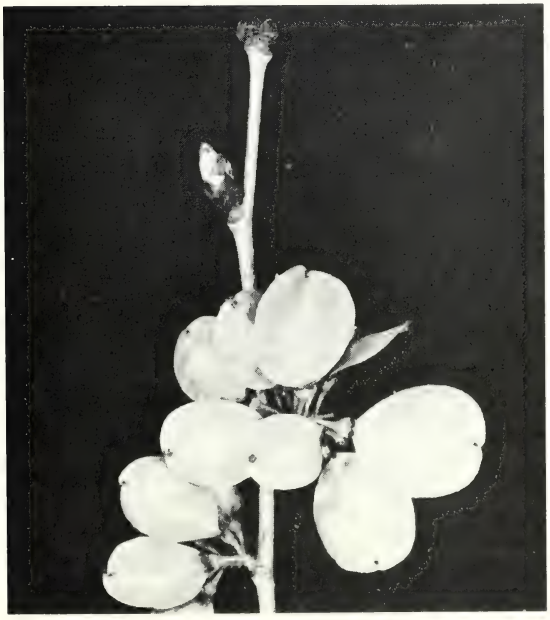
HABITAT: Rich soil, often calcareous, stream banks, river terraces, bottom lands; also on dry and poor sites.

HARVEST: Inner bark.

USES: Upon soaking in warm water, the inner bark of this tree produces a mucilage that can be used as a protective, demulcent, emmolient, laxative, and vulnerary. The pollen is allergenic. In Appalachia, a tea made from the bark is used as a laxative.

ULMUS RUBRA MUHL.

(ULMACEAE)



VERATRUM VIRIDE AIT.

(LILIACEAE)

COMMON NAMES: White hellebore, American falsehellebore, American hellebore, American white hellebore, bearcorn, big-bane, common swamp hellebore, devil's-bite, false hellebore, green hellebore, Indian poke, itchweed, pokeroot, swamp hellebore.

DESCRIPTION: A perennial that is coarse, erect, 2 to 8 feet in height. Stems are leafy, unbranched, and grow from short, thick rootstock to 1 foot long. Leaves are alternate, broadly ovate to elliptical, entire, with parallel veining. Flowers are greenish-white to purple, inconspicuous, and in pyramidal panicles 2 feet long.

FLOWERING PERIOD: May to July.

HABITAT: Swamps and low ground, meadows, and banks of streams.

HARVEST: Roots in fall after leaves have died.

USES: This plant is very poisonous. Its dried roots and rhizomes, when properly prepared, are a strong cardiac stimulant drug. It is emetic, diaphoretic, sedative, and analgesic.

VERATRUM VIRIDE AIT.

(LILIACEAE)

VERBASCUM THAPSUS L.

(SCROPHULARIACEAE)

COMMON NAMES: Common mullein, Aaron's rod, Adam's flannel, blanket leaf, bullock's lungwort, candlewick, cow's lungwort, feltwort, flannel leaf, flannel mullein, flannel plant, great mullein, hare's beard, hedge taper, ice leaf, Indian tobacco, Jacob's staff, Jupiter's staff, lady's foxglove, mullein, mullein dock, old man's flannel, Peter's staff, shepherd's club, torch-wort, velvet dock, velvet plant.

DESCRIPTION: A tall, weedy, unbranched, biennial that grows to 7 feet in height. It is hairy and soft. Leaves are widely oblanceolate and oblong 2 to 12 inches long. Flowers are yellow, densely arranged along a terminal club-like spike.

FLOWERING PERIOD: Late June to September.

HABITAT: Fields, rocky or gravelly banks, waste lands, roadsides, embankments, pastures, and meadows.

HARVEST: Leaves, and flowers, when fully open.

USES: The leaves and flowers are classed as astringent, antitussive, respiratory sedative, antifungal, and anodyne. A tea made from the leaves is used in Appalachia for colds. The Greeks and Romans dipped dried stalks in wax and used them as candles. The Spanish people of New Mexico smoked the dried leaves, wrapped in corn husks, as a treatment for asthma.

VERBASCUM THAPSUS L.

(SCROPHULARIACEAE)

VERBENA HASTATA L.

(VERBENACEAE)

COMMON NAMES: Blue vervain, blue verbena, ironweed, simpler's joy, verbain, wild hyssop.

DESCRIPTION: A perennial that grows to 4 feet in height, branched above. Leaves are serrated and 3-lobed with 2 sharp lobes arising from the base. Produces blue or blue-violet flowers on numerous narrow terminal spikes.

FLOWERING PERIOD: July to September.

HABITAT: Swales, damp thickets, shores, moist fields, meadows, and waste areas.

HARVEST: Herb and root.

USES: This herb reportedly has been used as an astringent, antipyretic, vulnerary, antirheumatic, tonic, and expectorant.

VERBENA HASTATA L.

(VERBENACEAE)

VERONICASTRUM VIRGINICUM (L.) FARW.

(SCROPHULARIACEAE)

COMMON NAMES: Culver's physic, Beaumont root, black-root, bowman's root, culver's root, physic root, tall speed-well, whorlywort.

DESCRIPTION: An erect, unbranched, smooth perennial that grows to 7 feet in height. Leaves are narrowly lanceolate and in whorls of 3 to 9 around the stem joints. Flowers are white to bluish, and crowded in several dense spikes on top of plant.

FLOWERING PERIOD: June to September.

HABITAT: Rich woods, thickets, moist meadows, and prairies.

HARVEST: Rhizomes and roots.

USES: The rhizome is reputed to be a laxative, emetic, cholagogue, and tonic.

VERONICASTRUM VIRGINICUM (L.) FARW.

(SCROPHULARIACEAE)

VIBURNUM NUDUM L.

(CAPRIFOLIACEAE)

COMMON NAMES: Possumhaw viburnum, larger withe-rod, possumhaw, shawnee haw, shonny haw, swamp haw, white rod.

DESCRIPTION: A perennial shrub that grows to 20 feet in height. Leaves are up to 5 inches long, varying from elliptic to ovate, with acute to rounded tops. Produces a spreading white or occasionally pink flower, and bitter berries in drupes.

FLOWERING PERIOD: May to early July.

HABITAT: Moist and open woods, wooded swamps, wet pinelands, and bogs.

HARVEST: Bark of root or stem.

USES: The bark is a uterine sedative, diuretic, antispasmodic, and tonic.

VIBURNUM NUDUM L.

(CAPRIFOLIACEAE)

VIBURNUM PRUNIFOLIUM L.

(CAPRIFOLIACEAE)

COMMON NAMES: Black haw, blackhaw viburnum, cramp bark, sheepberry, shonny, sloe, sloe-leaved viburnum, stagbush, sweethaw.

DESCRIPTION: A perennial shrub or small tree, 10 to 20 feet in height, with spreading branches. The dull-colored leaves are broadly ovate, opposite, and petioled, with finely serrated margins. Produces white flowers and dullish black oval fruit.

FLOWERING PERIOD: April to May.

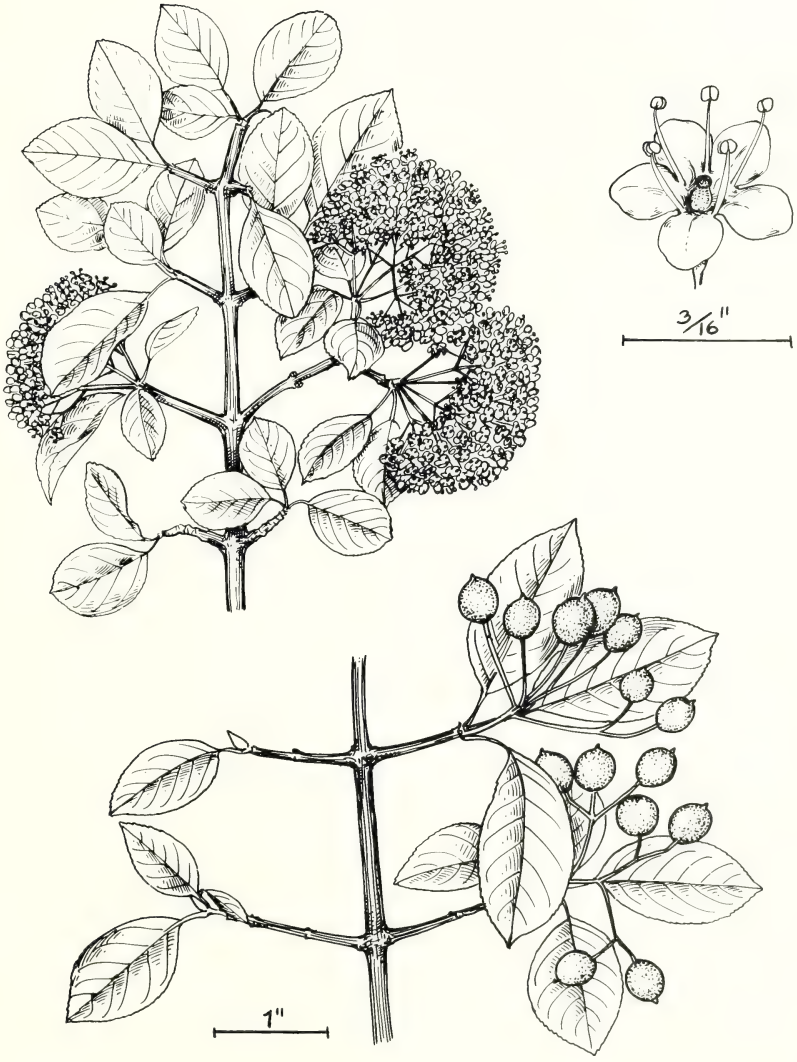
HABITAT: Thickets, borders of woods, and shores.

HARVEST: Bark of root or stem in the fall.

USES: This plant has the same qualities as *V. nudum*. In Appalachia, a root tea is used as a tonic.

VIBURNUM PRUNIFOLIUM L.

(CAPRIFOLIACEAE)



XANTHORHIZA SIMPLICISSIMA MARSH.

(RANUNCULACEAE)

COMMON NAMES: Yellow root, shrub yellowroot.

DESCRIPTION: A perennial low shrub that grows to 1 1/2 feet in height, with bright yellow wood. It bears a cluster of compound leaves, each with 5 lanceolate to broadly ovate, toothed, incised, or parted leaflets. Produces small brown-purple flowers on thin spikes.

FLOWERING PERIOD: April to May.

HABITAT: Damp woods, thickets, and stream banks.

HARVEST: Roots in fall.

USES: The roots are reputed to be valuable for making a bitter tonic and as a treatment for dyspepsia.

XANTHORHIZA SIMPLICISSIMA MARSH.

(RANUNCULACEAE)

XANTHOXYLUM AMERICANUM MILL.

(RUTACEAE)

COMMON NAMES: Pricklyash, American pricklyash, common pricklyash, northern pricklyash, pellitory bark, toothache bush, toothache tree, yellow wood.

DESCRIPTION: A shrub or small tree 5 to 10 feet in height. Leaves are alternate and compound, with 5 to 11 leaflets. Stems and petioles are often prickly. Flowers are greenish-white, small, and inconspicuous. Fruit is a reddish, globular to elliptic aromatic capsule.

FLOWERING PERIOD: April to May.

HABITAT: Rich woods and river banks.

HARVEST: Bark of stem in spring and fall, and fruit when ripe.

USES: Preparations made from the bark of this tree are reportedly used as a sudorific or diaphoretic, tonic, and antispasmodic. The fruit has some flavoring qualities also.

XANTHOXYLUM AMERICANUM MILL.

(RUTACEAE)

XANTHOXYLUM CLAVA-HERCULIS L.

(RUTACEAE)

COMMON NAMES: Hercules'-club prickly ash, Herculesclub, pepper wood, pricklyash, shrubby pricklyash, southern pricklyash, toothache tree, wild orange.

DESCRIPTION: A shrub or small tree 5 to 10 feet in height. Leaves are alternate, compound with 5 to 11 leaflets. Stems and petioles are often prickly. Flowers are greenish-white, small, and inconspicuous. Fruit is a reddish, globular to elliptic aromatic capsule, with sharp prickles.

FLOWERING PERIOD: April to May.

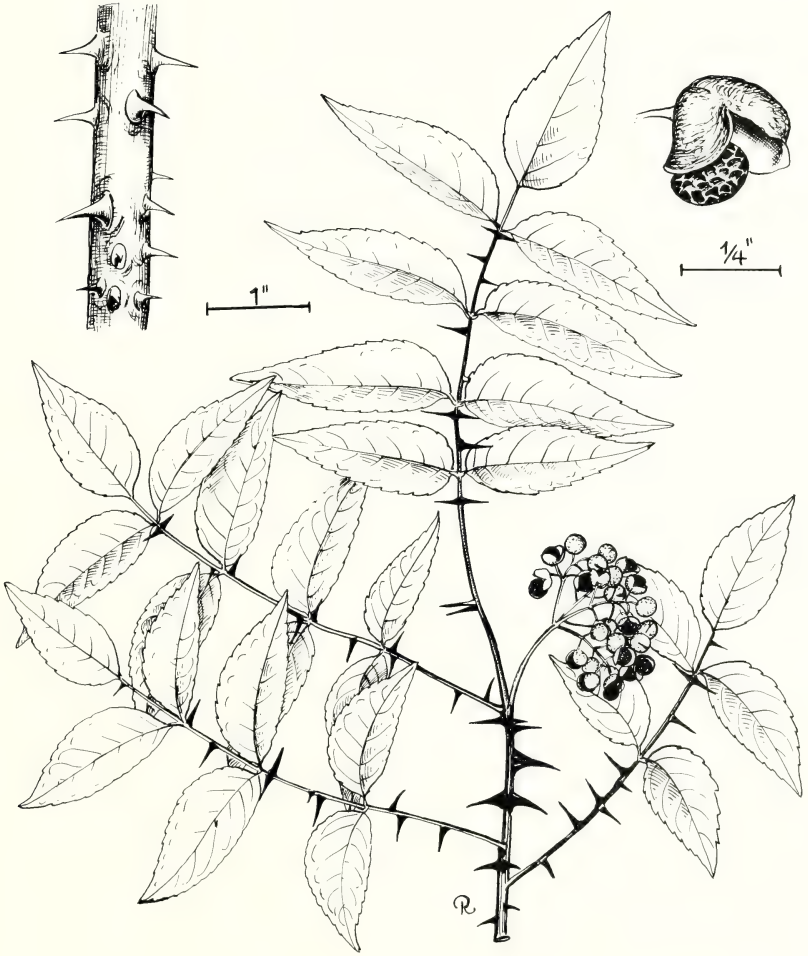
HABITAT: Sand hills, dry woods, and thickets.

HARVEST: Bark collected in spring and fall when ripe.

USES: This plant has been used as a sudorific and diaphoretic.

XANTHOXYLUM CLAVA-HERCULIS L.

(RUTACEAE)



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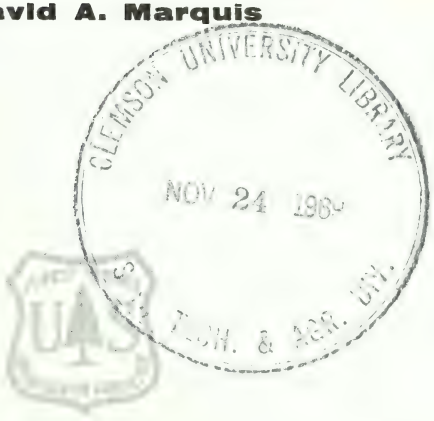
THINNING

in Young Northern Hardwoods: 5-Year Results

by David A. Marquis



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RICHARD D. LANE, DIRECTOR

The Author

DAVID A. MARQUIS received his bachelor of science degree in forestry from The Pennsylvania State University in 1955 and his master of forestry degree from Yale University in 1963. He joined the Northeastern Forest Experiment Station as a research forester, and was assigned first to the northern hardwood silviculture project in New Hampshire, where he studied problems of regeneration and thinning. Since 1965 he has been assigned to the timber management research staff at the Station's headquarters in Upper Darby, Pa.

THINNING

in Young Northern Hardwoods: 5-Year Results

WHAT EFFECTS FROM THINNING

THE YIELD of even-aged hardwoods can be increased by a program of regular thinnings. The questions are: How much increase can be expected? And what are the effects on quality?

The 5-year results from a long-term study of thinning in young northern hardwoods on the Bartlett Experimental Forest in New Hampshire show that heavy thinning increased crop-tree basal-area growth by 53 percent and crop-tree diameter growth by 64 percent. There were no adverse effects on tree quality, and overall stand quality has been improved.

THE STUDY

The Stand

The thinnings were made in a 25-year-old even-aged northern hardwood stand that originated after complete clearcutting of an old-growth stand in 1933-35. The stand covers about 22 acres, located on a lower north-facing slope, at about 1,100 feet elevation. The stony, sandy loam soil is a well-drained podzol derived mainly from granite and granitic gneiss glacial till. Paper birch site index on this area is estimated to be 70 feet at 50 years (based on curves prepared by *Curtis and Post 1962*).

The 25-year-old stand contained large numbers of sugar maple, beech, yellow birch, paper birch, and pin cherry; and moderate numbers of white ash, red maple, striped maple, aspen, and red spruce (fig. 1). There were over 4,000 stems 0.5 inches d.b.h. or larger per acre, representing 99 square feet of basal area. Average stand diameter was only 1.8 inches, but individual trees measured more than 8 inches in diameter. There were 130 stems per acre 4.5 inches d.b.h. or larger, representing

Figure 1.—The 25-year-old northern hardwood stand before thinning.

Table 1.—Twenty-five-year-old stand before thinning

Species	Entire stand[1]			Crop trees only		
	Stems per acre	Basal area per acre	Mean diameter	Stems per acre	Basal area per acre	Mean diameter
	No.	*Square feet*	*Inches*	*No.*	*Square feet*	*Inches*
			TOLERANTS			
Beech	1,029	11	1.3	24	1	2.7
Sugar maple	1,041	11	1.3	73	3	2.8
Striped maple	126	2	1.4	—	—	—
Conifers	58	1	1.8	—	—	—
			INTERMEDIATES			
Yellow birch	474	10	1.7	67	4	3.2
White ash	93	3	2.3	31	3	3.9
Red maple	176	5	2.0	21	2	3.5
			INTOLERANTS			
Paper birch	401	24	2.7	169	20	4.4
Aspen	54	9	5.1	—	—	—
Pin cherry	636	23	2.4	—	—	—
All species	4,088	99	1.8	385	33	3.7

[1] Includes all trees 0.5 inches d.b.h. and larger.

24 square feet of basal area. Although the tolerant species such as sugar maple and beech were the most numerous, (about 55 percent of the total number of trees), they were not the dominant species. The intolerant and intermediate species dominated the stand. They were the larger trees; they occupied much of the main crown canopy; and they represented 74 percent of the total basal area (table 1). For a more complete description of the stand before thinning, see Marquis (*1967*).

The Thinning

Twenty 1/4-acre plots were laid out in the study area, with 1-chain isolation strips between them. Plots were then assigned to blocks on the basis of total plot basal area, proportion of

weed species, and proportion of crop-tree species. Of numerous block arrangements tested by analysis of variance, the arrangement with maximum between-block variation in the above attributes was selected. This provided minimum variation among the plots within each block, and helped to reduce problems due to differences in original stand condition from place to place. There were 5 blocks of 4 plots each.

Approximately 100 crop trees were selected in each plot, or 400 per acre. Selection was on the basis of:

- Species. Paper birch, yellow birch, white ash, and sugar maple were given preference; but red maple and beech were accepted where necessary.
- Origin. Seedlings were given preference over sprouts.
- Crown class and size. Large dominant and codominant trees were given preference, but some intermediates were accepted where necessary.
- Bole condition. Clean, straight boles with a minimum of defects were given preference.

Attempts were made to select crop trees so that half of them would be paper birch and half would be other species that mature later than paper birch. In this way, a double harvest—first the short-lived paper birch and later the longer-lived species—could be obtained. Crop-tree tallies showed that an average of 385 trees had actually been selected per acre, representing 33 square feet of basal area in trees averaging 3.7 inches diameter (table 1).

After the crop trees were selected and marked, one of four treatments was randomly assigned to the plots in each block. These treatments consisted of the following:

1. *Heavy crop-tree thinning.*—All trees that competed directly with the crop trees were removed. Competition was judged as competition between crowns for growing space. An average of 615 stems per acre (mean diameter 3.2 inches), totaling 41 square feet of basal area, were removed in this treatment (table 2).

Table 2.—Twenty-five-year-old stand before and after thinning, by treatment

Treatment	Entire stand[1]			Crop trees only:
	Initial	Cut	Residual	Initial
		TREES PER ACRE *(Number)*		
Heavy	3,942	615	3,327	383
Light	3,908	326	3,582	373
Species	4,082	620	3,462	402
Control	4,253	0	4,253	392
		BASAL AREA PER ACRE *(Square feet)*		
Heavy	97.6	41.3	56.3	30.8
Light	96.9	25.1	71.8	33.5
Species	98.3	32.8	65.5	35.0
Control	99.6	0	99.6	31.2
		MEAN DIAMETER *(Inches)*		
Heavy	1.8	3.2	1.5	3.6
Light	1.8	3.4	1.6	3.8
Species	1.8	2.9	1.6	3.8
Control	1.8	——	1.8	3.6

[1] Includes all trees 0.5 inches d.b.h. and larger.

2. ***Light crop-tree thinning.***—A maximum of one of the trees competing with each crop tree was removed. In some cases (where the crop tree was a strong dominant or where a competing tree was adjacent to two crop trees) no competing tree was removed. An average of 326 stems per acre (mean diameter 3.4 inches) were removed, totaling 25 square feet of basal area (table 2).

3. ***Species thinning.***—All aspen, pin cherry, and striped maple were removed; all red maple sprout clumps were also removed except for sprouts selected as crop trees. There were only a few red maple sprout crop trees. In this treatment, trees specified were removed whether or not they were competing with the crop trees. An average of 620 stems per

acre (mean diameter 2.9 inches), totaling 33 square feet of basal area, were removed. This treatment, which was included because it would eliminate the need for marking crop trees in actual practice, resulted in the removal of about the same number of trees as the heavy crop-tree thinning. However, the trees removed were generally smaller than those removed in the other two treatments. The species thinning also tended to be more variable—very heavy in places where there were many weed species, and very light in places where there were few weed species (table 2).

4. *Control plots*.—No trees were removed (table 2).

Actual thinning was done in late August 1959 by applying sodium arsenite in frills (fig. 2). However, for sprout clumps in which one or two crop trees were to be retained, thinning was done by cutting the unwanted trees (fig. 3).

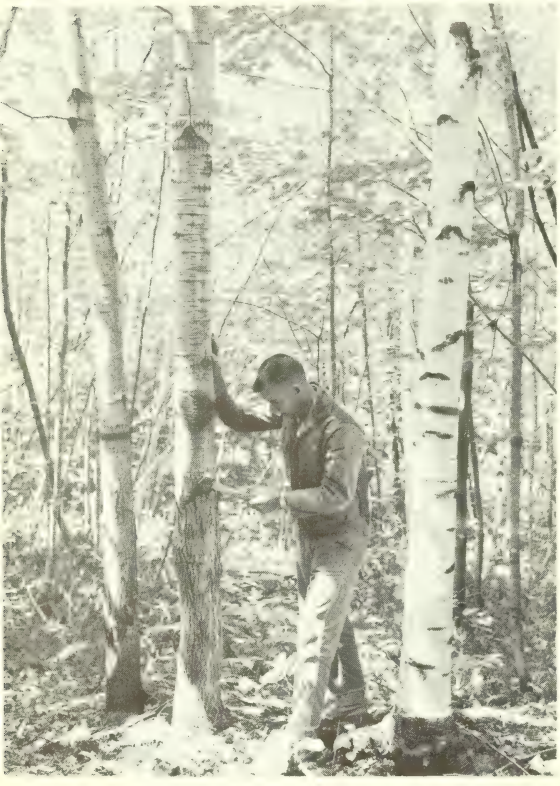

Figure 2.—Trees to be removed were killed with sodium arsenite, applied in frills. Here an aspen is being treated to release an adjacent paper birch.

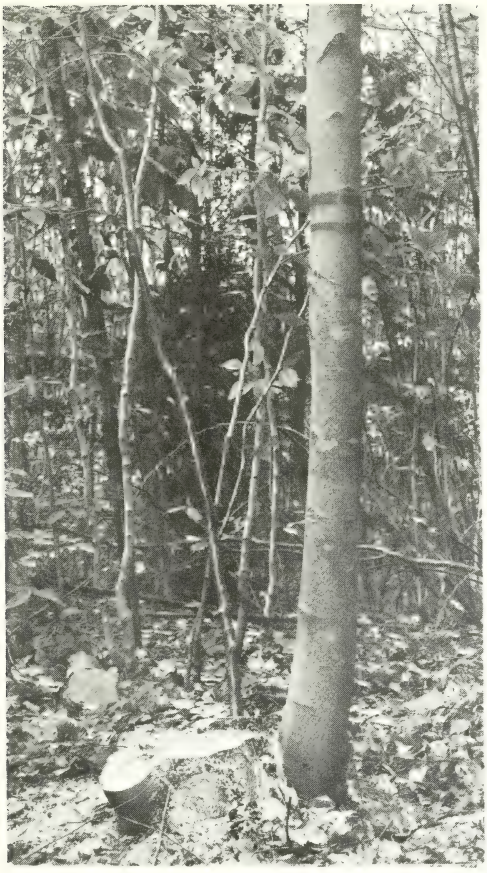

Figure 3.—This red maple crop tree was a member of a large sprout clump. The other stems of the clump have been cut to release it.

Measurements and Analysis

One hundred percent tallies were made of the crop trees and of the entire stand 0.5 inch d.b.h. and larger, both before thinning in 1959 and 5 years later in 1964. Similar tallies were made of all trees removed in the thinning. In addition, four trees of each crop-tree species present on each plot were selected at random for detailed measurements. These measurements included: diameter at breast height and at the top of the first 16-foot log (diameter at top of first 16-foot log measured only in 1964); merchantable height; total height; live crown length, crown area (basal area of crown projection), crown volume (crown area times crown length), crown class, and

crown vigor; clear length of bole (height to first live or dead branch, excluding epicormics); number and location of branches, epicormic branches, and bole defects; and bole quality class. These measurements permitted detailed evaluation of individual tree development.

Differences among the four treatments in net basal-area growth of the entire stand were tested for significance, using the analysis of variance. Differences among the four treatments in crop-tree diameter growth and crop-tree basal-area growth were also tested for significance, using the analysis of variance. Information from the sample crop trees was used in a variety of separate analyses. A series of sequential multiple-comparison tests (*Snedecor 1956*) was used to detect differences among treatments, among species, and among crown classes in such attributes as diameter growth, basal-area growth, height growth, cubic-foot volume, change in length of clear bole, change in number of branches and epicormic branches in the first log, changes in numbers of trees with forks, and changes in crown length, crown area, crown volume, and crown ratio.

Differences in diameter, basal area, crown area, and crown volume increment among treatments were tested further for significance, using the analysis of covariance and adjusting for small differences in initial tree size among the sample trees. Differences among treatments in the distribution of trees among the various crown classes, crown-quality classes, and bole-quality classes were tested with chi-square analyses. And finally, multiple regressions were computed, relating sample crop-tree diameter growth, basal-area growth, and crown-volume growth to various stem and crown variables.

RESULTS

RESPONSE OF THE ENTIRE STAND

Between 1,000 and 1,500 stems per acre—nearly one-third of the total number of stems present in 1959—died during the 5-year study period. Mortality was highest on the control plots where there was no thinning—400 to 500 more stems per acre

Table 3.—Response of the entire stand to thinning

Treatment	5-Year mortality per acre		Annual net basal-area increment per acre
	Number trees	*Percent*	*Square feet*
Heavy	1,019	31	4.0
Light	1,129	32	3.3
Species	977	28	4.9
Control	1,502	35	2.2

died on this treatment than on the three thinning treatments. Mortality was lowest on the species-thinning plots (table 3).

The reduced mortality noted on the thinned plots may be partially artificial because some stems that would have died anyway were cut. This is especially true on the species-thinning plots, where many small pin cherry and striped maple weed trees were removed even though they were not competing with the crop trees. However, the thinning almost certainly reduced mortality among the smaller trees in the stand. This reduction in mortality may not be important at this time because these trees are too small to be merchantable. However, if this trend continues after the trees reach merchantable size, salvage of this mortality by thinning will provide important increases in total stand yield.

Net basal-area growth of the entire stand was nearly twice as high on the three thinning treatments as it was on the control plots (table 3). The differences among treatments reflect the high mortality on the control plots and the lower mortality on the thinned plots. If an allowance is made for the extra mortality on the control plots, basal-area growth on the thinned plots is more nearly equal to that on the control plots.

RESPONSE OF THE CROP TREES

Little mortality occurred among the crop trees during the 5 years after thinning. An average of only one crop tree per acre died on each of the three thinning treatments, and an average of five crop trees per acre died on the control plots.

Growth Response of All Crop Trees

Diameter growth and basal-area growth were about one-third greater on the thinned plots than on the unthinned plots. These differences were highly significant (0.01 level). Growth was also significantly greater (0.05 level) on the heavy crop-tree thinning plots than on the other thinned plots (table 4).

All species responded well to thinning. The tolerant sugar maple and beech more than doubled their growth after heavy crop-tree thinning. Although the percentage increase on the other species was less, the actual increases were important for all species. Thinning also increased growth of trees in all diameter classes. The larger trees showed the largest absolute increase, although the percentage increase was greater for the smaller trees.

It is interesting to note that the basal-area growth on the heavy crop-tree thinning amounted to 3.2 square feet of basal area per acre per year on the crop trees alone. This does not include any growth made by the other 2,000 trees in the stand.

Table 4.—Growth response of all crop trees to thinning

Treatment	Basal-area growth per acre per year[1]	Diameter growth per year
	Square feet	*Inches*
Heavy	3.2	0.18
Light	2.7	.15
Species	2.7	.15
Control	2.1	.11

[1] Because of minor differences in original crop-tree basal area among the four treatments (table 2), crop-tree basal-area growth was adjusted to a common original basal area.

Growth Response of the Sample Crop Trees

The sample crop trees provide a means of comparing differences in growth among treatments, for not only d.b.h. and basal area, but also for height, volume, crown volume (crown

Table 5.—Growth response of the sample crop trees to thinning

Treatment	D.b.h. increment	Basal-area increment	Height increment	Volume, 1964	Crown-length increment	Crown-ratio change	Crown-volume increment
	Inches per year	*Square feet per tree per year*	*Feet per year*	*Cubic feet per tree*	*Feet per year*	*Ratio change per year*	*Cubic feet per year*
Heavy	0.18	0.0087	1.5	1.5	1.2	+0.008	514
Light	.15	.0075	1.6	1.6	1.1	+ .005	548
Species	.15	.0073	1.4	1.4	.8	+ .002	378
Control	.10	.0045	1.7	1.1	.9	− .001	306

basal area X crown length), crown ratio, and crown length (table 5).

Diameter increment at b.h. and basal area increment of the sample trees corresponded almost exactly with the results obtained from all crop trees, indicating that the samples accurately represented the entire crop tree stand.

Cubic-foot volume was computed as the mean of the basal area at b.h. and the basal area at 17 feet X a log length of 16 feet. No diameter measurements were taken at 17 feet in 1959, so volume increment cannot be determined at this time. However, differences in 1964 volume indicate that butt-log volumes are greater on the thinned plots than on the control plots. Differences among the three thinning treatments were not significant.

Differences in height increment were not significant. However, the general trend suggests that heavy thinnings may have reduced height increment slightly.

Crown-length increment did not vary significantly among treatments, but the general trend suggests that crown length is increasing faster on the more heavily thinned plots.

Although neither height increment nor crown-length increment varied significantly, the small differences that appeared in these two parameters combined to yield a significant difference in crown-ratio change between the heavy crop-tree thinning and the control stands. Differences among the other treatments

were not statistically significant. Relative crown size is decreasing on the unthinned plots while it is increasing on the thinned plots. If this change continues at the present rate for another 5 years, crown ratio will average 0.62 on the heavily thinned trees versus 0.53 on the unthinned trees.

Crown-volume increment was significantly greater on the two crop-tree thinning treatments than on the species-thinning treatment or the control plots.

Although every effort was made to minimize differences among plots at the beginning of the study, there were significant differences among treatments in original crown volume of the sample crop trees. This presented the possibility that the differences in growth reported above might be due, at least in part, to these initial differences in crown size. A series of covariance analyses was made, using initial crown volume and other variables as covariates. These analyses, in effect, provide a test for treatment after adjusting for initial differences in the covariate. The results of these covariance analyses indicate that the growth differences due to treatment were still highly significant.

Factors Affecting Growth of the Sample Crop Trees

To provide a better understanding of the factors that affect growth of the crop trees, a series of multiple regressions was computed for diameter, basal area, crown area, and crown volume increment. Independent variables included original d.b.h., basal area, crown area, crown volume, height, crown class, species, and treatment (the latter three entered as dummy or classification variables), and some of their cross products. Regressions incorporating these variables were computed by using a full screening technique.

In all cases, the single factor accounting for the largest proportion of the observed variance was either original d.b.h. (for diameter growth) or original basal area (for the other three dependent variables).

Although original crown volume (or original crown area) had

a significant effect by itself, the addition of crown volume to regressions that already contained d.b.h. (or basal area) did not produce a significant increase in the coefficient of determination (R^2). Original d.b.h. (or basal area) and original crown volume were apparently related closely.

Crown class, as evaluated with six classes in this study (see appendix for definitions), accounted for more of the variation than did the measured crown volume. And the addition of crown class to equations containing basal area (or d.b.h.), resulted in significant increases in the coefficient of determination. Although these results were somewhat unexpected, there may be reasons for them. First, crown class, as used in this study, provides a measure of competition as well as a measure of crown position, so it may be more sensitive than measures of crown position alone. Second, crown volume may not provide a very realistic measure of the effective crown size. In crowns of irregular shape—particularly on tolerant hardwoods that may have one or two very long branches at a point low on the bole—crown volume measured as it was here may not be too useful.

Although the addition of crown class to equations containing basal area (or d.b.h.) resulted in a significant increase in R^2, the increase was not as great as the addition of species or treatment dummy variables. Sequential addition of variables produced final equations containing these variables: basal area (or d.b.h.), species, and treatment. The addition of crown class or other variables to these equations did not produce further significant increases in the R^2 at the 0.05 level.

The best equation developed in this screening relates basal area increment to original basal area, species, and treatment. This equation accounts for 80 percent of the observed variation in basal-area increment. The regression of d.b.h. increment on similar independent variables accounts for 63 percent of the observed variation. The higher R^2 obtained with basal-area growth is probably due to the fact that basal area is a better measure of total wood production than is d.b.h. For example, diameter growth of 0.10 inch on a 6-inch tree represents considerably more wood than 0.10 inch on a 2-inch tree. In

contrast, 0.008 square feet of basal-area growth represents the same amount of wood area no matter what the tree diameter.

From this information above, separate regressions were computed for each of the six crop-tree species, relating basal area and d.b.h. increment to original basal area (or original d.b.h.), treatment, and the interaction between original basal area (or original d.b.h.) and treatment. Of the 12 regressions thus computed, all were found to be statistically significant. Coefficients of determination (R^2) for d.b.h. increment varied from 0.42 (beech and yellow birch) to 0.64 (paper birch), and

Table 6.—Predicted annual basal-area increment of 25-year-old crop trees on site index 70
(Square feet per tree per year)

Species	Treatment	Original d.b.h.				
		2	3	4	5	6
Paper birch	Heavy	—	0.005	0.010	0.014	0.019
	Light	—	.005	.009	.013	.017
	Species	—	.003	.009	.014	.020
	Control	—	.002	.007	.013	.018
White ash	Heavy	—	.008	.012	.016	—
	Light	—	.006	.011	.015	—
	Species	—	.007	.012	.016	—
	Control	—	.006	.011	.015	—
Red maple	Heavy	—	.006	.013	.020	—
	Light	—	.006	.011	.017	—
	Species	—	.007	.013	.018	—
	Control	—	.004	.006	.008	—
Yellow birch	Heavy	0.002	.006	.010	.013	—
	Light	.002	.004	.007	.009	—
	Species	.001	.004	.006	.008	—
	Control	.000	.003	.006	.008	—
Sugar maple	Heavy	.002	.007	.012	—	—
	Light	.001	.005	.009	—	—
	Species	.002	.005	.009	—	—
	Control	.001	.003	.006	—	—
Beech	Heavy	.004	.005	—	—	—
	Light	.001	.004	—	—	—
	Species	.001	.004	—	—	—
	Control	.000	.003	—	—	—

Table 7.—Predicted annual d.b.h. increment of 25-year-old crop trees on site index 70

(Inches per year)

Species	Treatment	Original d.b.h.				
		2	3	4	5	6
Paper birch	Heavy	—	0.13	0.17	0.22	0.26
	Light	—	.14	.17	.20	.23
	Species	—	.13	.17	.22	.27
	Control	—	.07	.12	.19	.25
White ash	Heavy	—	.20	.23	.25	—
	Light	—	.18	.21	.24	—
	Species	—	.18	.22	.26	—
	Control	—	.15	.20	.24	—
Red maple	Heavy	—	.17	.24	.32	—
	Light	—	.14	.23	.31	—
	Species	—	.17	.23	.29	—
	Control	—	.10	.13	.15	—
Yellow birch	Heavy	0.11	.16	.20	.24	—
	Light	.07	.10	.13	.16	—
	Species	.05	.09	.13	.18	—
	Control	.03	.07	.11	.16	—
Sugar maple	Heavy	.10	.17	.23	—	—
	Light	.07	.13	.19	—	—
	Species	.08	.14	.19	—	—
	Control	.05	.10	.15	—	—
Beech	Heavy	.12	.14	—	—	—
	Light	.07	.12	—	—	—
	Species	.06	.10	—	—	—
	Control	.03	.09	—	—	—

for basal-area increment they varied between 0.56 (beech) and 0.80 (paper birch and white ash).

Comparison of the plotted regression lines with the actual data strongly suggested that the relationships, although statistically significant, are not adequately expressed as a straight line. No attempts were made to fit curvilinear regression forms to the data because the relative importance of the various independent variables seems to have been well established in the previous regressions, and the values obtained from the linear regressions are adequate for growth-prediction purposes over the middle range of diameter classes represented by the data. Predicted

diameter and basal area increments for 25-year-old crop trees of various original d.b.h. and thinning treatments are presented in tables 6 and 7.

Quality Response of the Sample Crop Trees

Changes in some of the many attributes that affect tree quality are listed in table 8.

- *Changes in crown class.* At the end of the 5-year period there were nearly twice as many dominant and strong codominant trees (see appendix for description of classes) in the heavy crop-tree thinning as there were in the unthinned stands. And there were five times as many dominants in the heavy treatment as in the control plots (table 8). Chi-square analyses of changes in distribution of trees by crown class revealed that significantly more trees dropped in crown class in the unthinned stand than did in the thinned stands. Thus, heavy thinning has helped to retain more crop trees in the upper crown classes. Even in this treatment, however, the trend is for the number of trees in the upper crown classes to be reduced gradually as the trees get larger and approach mature size.

- *Change in bole quality class.* Changes in the distribution of trees by bole-quality class (see appendix for description of classes) did not vary significantly by treatment for all species together. Paper birch and red maple improved significantly after thinning; beech dropped significantly in bole quality after thinning; ash improved regardless of treatment; and sugar maple and yellow birch did not change significantly after thinning. However, the overall trend was for a slight improvement in bole quality for the stand as a whole. Most of these changes in bole quality were due to a general reduction in the number of branches or to changes (increase or decrease) in the number of epicormic branches.

- *Changes in epicormic branching.* Individual species varied considerably in the development of epicormic branches

Table 8.—Quality responses of the crop trees 5 years after thinning

Response	Heavy	Light	Species	Control
Proportion of trees in dominant crown classes[1] ..... percent ..	10	9	6	2
Proportion of trees in dominant and strong codominant crown classes[1] ..... percent ..	49	40	40	27
Changes in the proportion of trees in bole class 1 and 2[1] ..... percent ..	+3	+4	+3	+1
Changes in proportion of trees with no epidermic branches ..... percent ..	-9	-27	-18	-9
Trees with increased number of epicormic branches ..... percent ..	41	59	49	57
Increases in length of clear bole .... feet per year ..	0.7	0.6	0.8	0.8
Proportion of live branches in the butt log that died during the time ..... percent ..	45	49	52	55
Changes in proportion of trees with forks in the lower 25 feet of bole ..... percent ..	-1	+4	0	+2
Taper—ratio of diameter at 17 feet to d.b.h. ..... ratio ..	0.79	0.80	0.78	0.77

[1] See appendix for description of crown classes and bole classes.

during the 5-year period after thinning. No epicormic branches were found on either paper birch or white ash crop trees. The number of trees with epicormic branches increased by nearly 30 percent among the other four species, but this increase occurred on both thinned and unthinned trees. Differences among treatments were not significant. In general, the lighter thinnings seemed to cause epicormic branch formation on more trees than the heavier thinnings; but this

trend was not significant and it is probably just a chance occurrence.

Epicormic branches were common on yellow birch, beech, and sugar maple even before thinning. About half the crop trees of these species had epicormic branches. However, these epicormic branches were generally little more than short shoots with one or two leaves; they were seldom large enough to be true branches and probably do not represent important defects in their present form. We shall need additional time to determine whether or not these little branches will persist and grow to become important sources of defect as the trees reach merchantable size.

- *Changes in length of clear bole.* Changes in length of clear bole (height to the first branch, either dead or alive) during the period did not follow any consistent pattern, and differences among treatments were not statistically significant. Overall increase in length of clear bole averaged nearly 4 feet in 5 years.

  The proportion of live branches in the first log that died during the 5-year period is another measure of natural pruning. Although no statistical tests were made of these data, there appeared to be slightly fewer live branches dying in the heavily thinned treatment than in the unthinned treatment. A longer period of time will be required to evaluate this effect.

- *Changes in numbers of forks.* Changes in the numbers of crop trees with forks below 25 feet revealed no significant differences among treatments.

- *Changes in stem taper.* Because diameter at 17 feet was not measured in 1959, changes in stem taper could not be determined. However, comparisons of taper present in 1964 revealed no significant differences among treatments, except that the light crop-tree thinning had significantly less taper than the control. This is probably just a chance occurrence.

DISCUSSION

One effect of the thinning in this 25-year-old stand is rather definite: diameter and basal-area growth of residual crop trees was stimulated at breast height. The amount of the increase varied with degree of thinning, species, and original tree size. Increases in growth were significant statistically, and these increases are economically and silviculturally highly significant as well.

For example, if we assume that repeated thinnings would maintain growth at the present rates, it should take the heavily thinned paper birch crop trees about 15 years less time to reach an average diameter of 13 inches d.b.h. than it will those in the unthinned stands. Or, heavily thinned yellow birch crop trees should reach 18 inches average diameter nearly 50 years before unthinned yellow birch. If the actual growth rate falls off as the stands get older, but relative differences between thinned and unthinned crop trees remain similar, then the reductions in rotation due to thinning will be even larger than above. Such differences suggest that thinnings begun early and repeated regularly will materially reduce the rotation age required to grow a given-size tree or increase tree size attainable at a given age.

Of the three thinning treatments used, the heavy crop-tree thinning has resulted in best growth. Heavy crop-tree-thinning increased crop-tree basal-area growth by 53 percent and diameter growth by 64 percent over those of the unthinned control plots.

The increased bole growth resulting from thinning was accompanied by—and perhaps the result of—increased crown expansion among the thinned trees. Crown ratio of thinned crop trees increased, whereas crown ratio of unthinned crop trees decreased. Heavily thinned crop trees produced 36 percent more crown-area increment and 68 percent more crown-volume increment than unthinned crop trees. And thinning helped to maintain the crop trees in the upper crown classes; 5 years after thinning there were twice as many dominant and strong

codominant crop trees on the heavily thinned plots as on the control plots.

Although 5 years is not long enough to determine how thinning will affect quality of the eventual yield, there have been no reductions in quality to date that can be attributed to thinning. Changes in bole-quality classification of the crop trees was not affected by treatment. Although the number of epicormic branches increased over the 5-year period, the increases were as large on the unthinned plots as on the thinned plots. Changes in other parameters, such as length of clear bole, numbers of forks, and stem taper, did not differ significantly among treatments. Overall stand quality should improve after thinning, since growth is now being concentrated on the best stems of the more valuable species.

Data presented in this paper should be useful in estimating the short-term growth increases that can be expected from thinnings in young northern hardwoods. Economic evaluations of these data are now being made. These should provide forest managers with some guides on whether or not investments in thinnings are desirable for short-term product goals such as paper birch boltwood. And evaluations of the effects of thinning on long-term product goals such as sawtimber and veneer will be possible after additional years of growth and quality data are obtained.

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APPENDIX

QUALITY CLASSIFICATION

The quality classification used in this study is a three-attribute classification indicating crown position and relation to surrounding trees (crown-class), crown development, and bole condition. Criteria for classification are listed below:

CROWN POSITION & RELATION TO SURROUNDING TREES

100—***Strong dominant.*** Tree taller than all its immediate neighbors. Crown extends well above the general level of the crown cover and receives full light from above and considerable light from the sides. DOMINATES ALL IMMEDIATE NEIGHBORS.

200—***Dominant.*** Tree slightly taller than its immediate neighbors. Crown extends somewhat above the general level of the crown cover and receives full light from above and considerable light from the sides. COMPETES WITH OTHER DOMINANTS OR CODOMINANTS, WHICH ARE SOMEWHAT INFERIOR.

300—***Codominant.*** Tree with crown formed at the general level of the crown cover. Receives full light from above but comparatively little from the sides. COMPETES WITH OTHER CODOMINANTS, BUT IS IN NO IMMEDIATE DANGER OF BEING CROWDED OUT.

400—***Weak codominant.*** Tree with crown formed at the general level of the crown cover. Receives full light from above but very little from the sides. COMPETES WITH OTHER CODOMINANTS OR DOMINANTS, WHICH ARE SUPERIOR IN VIGOR.

500—***Intermediate.*** Tree shorter than those above but with crown extending into the crown cover formed by the dominants and codominants. Receives a little direct light from above but none from the sides. COMPETES WITH TREES OF HIGHER CROWN CLASS AND DEVELOPMENT.

600—***Overtopped.*** Tree with crown entirely below the general crown level. Receives no direct light from above.

CROWN DEVELOPMENT

10—*Good.* Very large, well-developed, well-rounded crown, not compressed by neighboring crowns.
20—*Average.* Well-developed vigorous crown, slightly compressed by neighboring crowns, but not flattened.
30—*Fair.* Smaller than desirable crown, compressed on all sides or flattened on one side.
40—*Poor.* Very small spindly, flattened crown; very low vigor.

BOLE CONDITION

1—*Good.* No live branches, no epicormic branches in first 17 feet. Allows these defects[1]:
Slight lean.
One slight crook and/or one slight sweep.
Slight wounds.

2—*Medium.* Allows one live branch and/or fewer than 5 epicormic branches in first 17 feet. Also allows these defects:
Slight lean.
Slight crook.
Slight sweep.
Moderate crook if located so 12-foot log still obtainable.
Moderate sweep if located so 12-foot log still obtainable.
Slight wounds.

3—*Fair.* Allows any number of live branches or epicormic branches. Also allows the following defects:
Slight or moderate lean.
Slight or moderate crook.
Slight or moderate sweep.
Severe crook if located so 12-foot log still obtainable.
Fork.
Slight or moderate wounds.

4—*Poor.* Allows any number of defects of any severity.

Example: 432 would represent a weak codominant of fair crown development and medium bole condition.

[1] The various types of bole defects were carefully defined as to type and severity. Photographs of typical defects were used to aid in maintaining uniformity of classification.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The Rate of Value Increase for YELLOW-POPLAR and BEECH

by
Joseph J. Mendel
George R. Trimble, Jr.

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The Authors

JOSEPH J. MENDEL, principal economist, received his Bachelor of Science degree in Forestry from the University of Michigan in 1941, and his Master's and Ph.D. degrees in Agricultural Economics from Ohio State University 1963 and 1965, respectively. He has also studied at the University of Wisconsin and the University of Cincinnati. He joined the Northeastern Forest Experiment Station in 1946, working first on forest surveys. In 1952 he transferred to the Washington Office of the Forest Service, in the Division of Forest Economics. After 6 years in Washington he accepted a position as research forester with the Central States Forest Experiment Station at Columbus, Ohio. When this Station was discontinued in 1966 Dr. Mendel transferred back to the Northeastern Station, where he is now specializing in forest economics at the Station's research unit at Columbus, Ohio.

GEORGE R. TRIMBLE, JR., project leader in timber-management research, received his Bachelor of Science degree in Forestry from the University of Maine in 1937. He has taken post-graduate courses at Delaware, Duke, Indiana, and West Virginia Universities as well as the U. S. Department of Agriculture Graduate School. He joined the U. S. Forest Service in 1932, and worked first on the White and Green Mountain National Forests in Maine, New Hampshire, and Vermont. In 1939 he joined the Northeastern Forest Experiment Station as a research forester. Mr. Trimble has worked on forest-management problems throughout most of the Northeastern States. He is now located at the Northeastern Station's Timber and Watershed Laboratory at Parsons, West Virginia.

The Rate of Value Increase for YELLOW-POPLAR and BEECH

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Introduction

AN IMPORTANT OBJECTIVE in forestry is to earn the highest return on capital invested in growing timber. To achieve this objective, timber growers not only must know the proper silvicultural methods to employ, but also must be able to determine when the timber is ready to harvest so as to obtain the maximum return.

The financial maturity concept is a method of economic analysis that can be used to determine not only the rate at which trees increase in value but also when that rate of value increase falls below the rate of return desired by the timber grower. This is the point of financial maturity, the time when the timber is ready to be harvested.

By calculating the rate at which trees increase in value, timber owners will be able to prepare marking guides for prescribing the diameters at which trees of given vigor, grade, and merchantable height are financially mature. It is not designed to supplant professional judgment based on such natural factors as growth, vigor, and log quality. Rather, it blends an economic factor with the natural factors so that a more refined definition of tree maturity can be made.

This paper describes the methodology and develops the basic data from which the rates of value increase over a 10-year period were calculated for yellow-poplar (*Liriodendron tulipifera* L.) and beech *(Fagus grandifolia* Ehrh.)

The Rate of Value Increase

The rate of value increase is, as the name implies, the rate at which trees increase in value. The cornerstone of the financial maturity concept, it is determined by three components: (1) the present value of the tree; (2) the prospective future value of the tree, considering growth increase in diameter and in merchantable height and possible improvement in quality; (3) the time period between the determinations of present value and prospective value. Given this information, the timber grower can determine the rate of value increase by solving for r in the compound-interest formula:

$$(1 + r)^n = \frac{V_n}{V_o}$$

where r is the rate of interest.
n is the time period.
V_n is the prospective value.
V_o is the present value.

Despite the relative simplicity of this compound-interest formula, considerable work is necessary to develop the present and prospective values. To determine present value, basic data on lumber grade yields and prices had to be developed. And to establish prospective value, data on growth and quality improvement were necessary for projecting the development of the tree over a 10-year period.

Determining Present Value

Present value of a single tree is related to its volume and quality, lumber prices, and conversion costs. Tree volume was expressed in board feet, International 1/4-inch kerf rule. Quality evaluations were based on log grades developed by the U. S. Forest Products Laboratory for factory-lumber logs and defined in the field manual. *A Guide to Hardwood Log Grading (revised) (Ostrander and others 1965).*

The observations made in the field included diameter (d.b.h.) by 2-inch classes, log length in the tree by ½-log heights to top of merchantability (8 inches d.i.b. or crown), and the grade of each log. In addition to the three factory-lumber log grades (1, 2, and 3), a fourth class was recognized that included both construction and local-use logs. These logs, though better than those in the cull-log class, are too rough or knotty for use as lumber.

Lumber grade yields for different species—log grades—and size-class combinations were obtained from the U. S. Forest Products Laboratory publication, *Hardwood Log Grade for Standard Lumber (Vaughan, Wollin, McDonald, and Bulgrin 1966).* Prices used were those reported in the *Hardwood Market Report (Lemsky 1962-1966).*

In computing present value, we used the quality-index system to determine the log value in terms of the amount and value of the lumber the trees contain. The procedure was: (1) develop log quality indexes and tree quality indexes, and (2) determine the conversion value, present tree value.

LOG QUALITY INDEXES AND TREE QUALITY INDEXES

The quality-index system (Q. I.), originated by A. M. Herrick in 1946 and refined by other researchers since then, was used to put log grades on a lumber-value basis *(Herrick 1946).* Q. I. is a single number that expresses the relative value of a log or tree as determined by the amount and value of the different grades of 4/4 lumber (1 inch thick) that can be sawed from the log or tree. In formula form it reads:

$$\text{Q. I.} = (\%\ \text{FAS} \times \text{P.R.}_{\text{FAS}}) + (\%\ \text{SEL} \times \text{P.R.}_{\text{SEL}}) + (\%\ \#1\text{C} \times \text{P.R.}_{\#\,1\text{C}}) \text{ --- } + (\%\ \#3\text{A} \times \text{P.R.}_{\#\,3\text{A}})$$

where —

% FAS is the percentage of the total volume of the lumber that could be sawed from the log or tree that would grade First and Seconds.

P.R._{FAS} is the standard price relative for FAS lumber *(Herrick 1956).*

Thus two sets of data are essential for developing Q.I.: (1) lumber grade yields by log grade, log diameter, and species; and (2) lumber price relatives (price ratios with No. 1 Common as the base grade) derived from regional price reports and averaged for 5 years.

Lumber grade yields were obtained from the Forest Products Laboratory guide, *Hardwood Log Grades for Standard Lumber.* Because of the erratic nature of the published yields—due mainly to the small sample, especially in the larger diameter classes —it was necessary to resort to hand-curving the information to make it useful in developing the Q.I.

Price relatives were derived from the *Hardwood Market Report* for the base period 1962-66. Prices were averaged over the 5-year period, and the price relatives between these average prices for the various grades and the average price for No. 1 Common lumber were computed. Thus the price relatives for No. 1 Common are always 1.00, whereas the price relatives for lumber grades FAS and SEL are above 1.00; and the price relatives for No. 2 Common, 3A, and 3B are below 1.00 (table 1).

Log quality indexes were then computed for each species by log grade and diameter.

The next step was to develop tree quality index, using the formula:

$$\begin{aligned}\text{Tree quality index} = {} & (\%\text{ of tree volume in 1st log} \\ & \times \log \text{Q.I.}_{\text{1st log}}) \\ & + (\%\text{ of tree volume in 2nd log} \times \log \text{Q.I.}_{\text{2nd log}}) \\ & + (\%\text{ of tree volume in nth log} \times \log \text{Q.I.}_{\text{n log}})\end{aligned}$$

The percentage of tree volume in each log was determined by means of a hardwood taper table, which provides the diameter inside bark at the small end of each log, and the International 1/4-inch kerf volume table, which provides the volume of each log as well as the volume of the total merchantable height of the tree.

Tree quality indexes were developed for each of the sample trees; and by means of regression analysis, they were developed for each species by butt-log (for log grades 1, 2, and 3), diameter and merchantable height (appendix, tables 9 and 10). Examination of the log-grade data for trees with butt-log grades below

Table 1.—*Lumber price relatives for two species of Appalachian hardwoods**

Lumber grade	Yellow-poplar	Beech
FAS	1.45	1.28
FIF	—	1.21
SEL	1.38	—
SAPS	1.31	—
1C	1.00	1.00
2A	.69	—
2B	.47	—
2C	—	.53
3A	.25	.40
3B	.25	.36

*Based on *1962-66 Hardwood Market Report* prices for Appalachian hardwoods (f.o.b. mills in the Johnson City, Tennessee, area), with 4/4 thickness, plain-sawed No. 1 Common grade as reference.

3 showed that in almost all cases such trees had a tree grade below 3 regardless of species, diameter, or log height. Therefore a tree Q.I. of 0.400 was assigned to all such trees.

DEVELOPING PRESENT VALUES

The ease in using tree quality indexes is well illustrated in determining conversion values—present tree values. Only the volume of the tree and the price of No. 1 Common lumber is needed to convert the tree quality index into monetary terms. The procedure is relatively simple.

The *Hardwood Market Report* of 6 January 1968 *(Lemsky 1968)* was used to obtain prices of 4/4 No. 1 Common lumber. Appalachian hardwood prices f.o.b. at mills in the Johnson City, Tennessee, area were used. Prices were $162.00/M board feet for 4/4 No. 1 Common yellow-poplar and $133.00/M for 4/4 No. 1 Common beech.

The gross value per M of the lumber in trees of various diameters and merchantable heights was determined by multiplying the tree quality index by the appropriate price per M.

To determine the net value/M of the lumber in the tree, it was necessary to deduct conversion costs. These are all the direct costs involved in converting the standing tree into lumber. These

costs consist mainly of labor and materials used in felling the tree; and making, transporting, and sawing the logs into lumber.

Conversion costs can account for the greatest variation from any norm that might be established here. Every logging chance will differ in terms of topography, need for woods roads, and proximity to a main haul road as well as distance to the mill. Logging crews will vary in efficiency of both men and equipment. Similarly, milling costs will vary according to the efficiency of personnel and equipment. Also in some cases, allowances for profit and risk, as well as brokerage fees for marketing, are regarded as logical costs and should be included as part of the conversion costs. However, it should be recognized that in some cases such charges are not made and that brokerage fees are avoided by selling direct. For this study, an average conversion cost of $70.00 per M board feet for a 16-inch d.b.h. tree was used. Costs were adjusted and curved by tree d.b.h., and the resulting values were considered applicable (table 2).

After we determined the net value/M of the lumber in the tree, we calculated conversion value by multiplying the net value/M by the appropriate tree volumes.

Thus, once tree quality indexes are established, the calculation of present value can be summarized as follows:

1. (Tree Q.I. $\times$ price for #1C/M) $=$ gross value/M
2. (Gross value/M $-$ conversion costs) $=$ net value/M

Table 2.—*Conversion costs for hardwood trees*

Tree d.b.h. (inches)	Cost per thousand bd. ft.
12	$78.85
14	74.50
16	70.00
18	65.70
20	61.35
22	57.00
24	53.50
26	52.25
28	51.95
30	51.85

3. (Net value/M $\times$ volume in tree) = conversion value or present tree value

Determining Prospective Value

Prospective value was based on a calculated increase in tree value over the next 10 years, assuming there would be no change in the market price of lumber. (An increase in price would result in a higher rate of value increase, while a lower market price for lumber would result in a lower rate). Prospective value is the present value plus the increase in value due to diameter growth, the increase in merchantable height, and possible improvement in quality.

D.B.H.-GROWTH PREDICTIONS

To put growth on a basis that the forest manager can apply to his particular situation, we took into account: (1) the ability of an area of forest land to grow trees—site quality; (2) the competitive condition of a tree in the stand—vigor class; and (3) the size of the tree. Diameter-growth data was developed differently for the two species, and the methodology is discussed separately.

Yellow-Poplar

The basis of our d.b.h. growth computations was a study by Holcomb and Bickford *(1952)*. In this study, 10-year d.b.h. growth rates were determined from core data for 900 trees by vigor class (see appendix for definitions) and tree size. We recognized that site quality influences diameter-growth rates, but unfortunately the data were taken without identification of site. However, yellow-poplar, as an important component of stands in this general area, is largely restricted to site indexes between 75 and 95 (70 to 85 for oak); and within this range of sites, diameter growth differences due to site quality are relatively small.

The data were taken in well-stocked even-aged stands. The

effect of stand density variations was not measured, but it is strongly reflected in tree vigor classes. Only for vigor class I trees did growth vary with d.b.h.; it decreased as tree size increased. Though this trend was detected only for vigor I trees, we know that it is a natural one; and adjustments were made so that it was reflected in the growth rates of the other vigor classes also—except vigor IV, which was eliminated from consideration because vigor IV yellow-poplar would never be left as crop trees (appendix, table 11).

Beech

Beech is a slow-growing tree under the best conditions *(Campbell 1955; Trimble 1968)*. Moreover, beech improves very slowly in log grade as diameter increases *(Trimble 1965)*. For this reason we felt that a detailed comprehensive growth study to determine financial maturity was unwarranted.

Growth was studied on 63 sawtimber-size stems. About half the data came from repeat measurements, and half came from core sampling. By using the oak site index scale *(Trimble and Weitzman 1956)*, we found samples on sites 60, 70, and 80. Most were on site 70; this is the typical site where beech—and sugar maple—are most common in this area. Ten-year d.b.h. growth by vigor classes, all diameters included, averaged: vigor I—1.27 inches; vigor II—0.92 inches; and vigor III—0.86 inches. Vigor IV beech of sawlog size are rare—except for cull trees—and we found no examples. The growth data were adjusted to reflect an effect of increasing tree size on d.b.h. growth (appendix, table 12).

In applying the diameter growth predictions to the calculation of the rate of value increase, we made two assumptions:

- That vigor classes remained the same during the next ten years, which is conservative. Under a forest-management cutting program, vigor would improve.

- That vigor IV trees would never be considered as leave trees, so no calculations of rate of value increase need be made for this class.

HEIGHT-GROWTH PREDICTIONS

A further consideration involved in determining prospective value is that trees may increase in merchantable height. To guide the projection of log-height increase during the 10-year period for which value increases are projected, the following assumptions were adopted:

- That trees with a d.b.h. growth of 2.0 inches or more during the 10-year period could increase a full 16-foot log in merchantable height. Trees growing less than 2.0 inches d.b.h. in 10 years were limited to a half-log increase in merchantable height.
- That log-height increases are related to d.b.h. For example, a tree that has a 16-foot merchantable stem at 20 inches d.b.h. is limited in its merchantable length by stem breakup into crown; and its merchantable length will not increase with d.b.h. growth. The following log-height-increase limitations were set for computation purposes:

Present d.b.h. (inches)	*Tree height classes that will not increase in height in next 10 years*
16	1-log trees.
18	1- and 1½-log trees.
20	1-, 1½-, and 2-log trees.
22	1-, 1½-, 2-, and 2½-log trees.
24	1-, 1½-, 2-, 2½-, and 3-log trees.
26	No increase in log height for any tree 26 inches d.b.h. or larger.

- That maximum log height used in the computations was 64 feet for yellow-poplar and 48 feet for beech.

QUALITY-IMPROVEMENT PREDICTIONS

Quality denotes value, and in the development of a tree any improvement in quality will result in an appreciable increment in the rate of value increase. Early determination of trees most likely to improve in quality is probably the most important consideration that can be made by the timber grower to attain the

greatest rate of value increase. We used these assumptions to guide our quality-improvement predictions:

- That the maximum butt-log grade improvement in the 10-year period is one grade class. This may be a conservative estimate for the better sites.

- That for yellow-poplar there is little prospect of grade improvement for butt-log grade 3 stems above 22 inches d.b.h. (*Trimble 1965*). So no grade improvement was computed for stems larger than 22 inches that were rated butt-log grade 3. Moreover, there is little likelihood that yellow-poplar stems larger than 26 inches d.b.h. that are now grade 2 will improve. So no grade improvement was computed for those trees that were larger than 26 inches. In trees larger than 15 inches d.b.h., no improvement in butt-log grade was computed for trees with butt-log grade below 3—the construction or local-use logs.

Beech apparently has grade-improvement potential, for both grade 3 and grade 2 logs, to larger size than yellow-poplar; so grade-improvement possibilities were computed for grade 3 and 2 beech butt-logs through the 32-inch d.b.h. class. Butt-log grades below 3—construction and local-use logs—in beech continue to improve in grade into higher d.b.h. classes than most species. Quality increases of butt-log grade below 3 were computed up to the 18-inch d.b.h. class.

DEVELOPING PROSPECTIVE VALUE

Three factors were considered in the development of the tree over the 10-year projection period to determine the prospective value; diameter growth, height growth, and quality improvement. Given these factors, with full consideration of the extent and occurrence of the restrictions, we could project the development of the tree and estimate its diameter, grade, merchantable height, and conversion value at the end of the 10-year period. Several combinations of these factors are possible, such as no increase in grade or merchantable height, an increase in both grade and merchantable height, or an increase in grade but not height.

The number and extent of these combinations are limited only by our assumptions concerning these factors (table 3).

For example, assume a yellow-poplar vigor I tree of 16-inch d.b.h. butt-log grade 2 with 24 feet of merchantable height. We can expect a 10-year growth of 2.6 inches (table 11, in appendix); so the predicted future d.b.h. of this yellow-poplar is 18.6 inches. Our quality-improvement assumptions indicate that this tree can improve one log grade in the 10-year period; the future tree can have a butt-log grade of 1 or 2. With regard to merchantable height, our assumptions permit an increase up to a full 16-foot log; so we have three possible merchantable heights —24, 32, and 40 feet. Thus six possible combinations of these factors exist:

Diameter (inches)	*Butt-log grade*	*Merchantable height (feet)*
18.6	2	24
	2	32
	2	40
	1	24
	1	32
	1	40

Future conversion values for these possible combinations are calculated in the same manner as present value.

Determining Rate of Value Increase

Computation of rate of value increase is based on the relationship between the present value and the prospective value 10 years hence, as depicted in the compound interest formula

$$(1 + r)^n = \frac{V_n}{V_o}$$

which has been previously explained.

Continuing with the example of the 16-inch yellow-poplar used above, we could now calculate the rate of value increase for the six possible future combinations. Given the units of present tree value (table 3, column 4) and prospective tree value (column 8), it was relatively easy to determine the value for V_n/V_o

Table 3.—*Determining rate of value increase for 16-inch d.b.h., vigor I, yellow-poplar, with site index 85*

Present				Future						
D.b.h. (1)	Butt-log grade (2)	Log height, feet (3)	Conversion value, dollars (4)	D.b.h. (5)	Butt-log grade (6)	Log height, feet (7)	Conversion value, dollars (8)	Ratio V_n/V_o (9)	Percent rate of return (10)	10-year value increase, dollars (11)
16	1	16	5.48	18.6	1	16	9.75	1.780	5.9	4.27
16	2	16	4.83	18.6	2	16	8.38	1.734	5.7	3.55
					1	16	9.75	2.018	7.3	4.92
16	3	16	2.08	18.6	3	16	4.44	2.136	7.9	2.36
					2	16	8.38	4.027	14.9	6.30
16	1	24	7.69	18.6	1	24	13.66	1.777	5.9	5.97
					1	32	16.49	2.145	7.9	8.80
					1	40	18.83	2.450	9.4	11.14
16	2	24	6.34	18.6	2	24	11.08	1.748	5.7	4.74
					2	32	12.53	1.977	7.1	6.19
					2	40	13.26	2.093	7.7	6.93
					1	24	13.66	2.155	8.0	7.32
					1	32	16.49	2.602	10.0	10.15
					1	40	18.83	2.971	11.5	12.49
16	3	24	2.76	18.6	3	24	6.03	2.184	8.1	3.27
					3	32	7.04	2.547	9.8	4.27
					3	40	7.73	2.798	10.8	4.97
					2	24	11.08	4.011	14.9	8.32
					2	32	12.53	4.534	16.3	9.77
					2	40	13.26	4.800	17.0	10.50

16	1	32	9.63	18.6	1	32	16.49	1.711	5.5	6.85
					1	40	18.83	1.954	6.9	9.20
					1	48	21.19	2.199	8.2	11.56
16	2	32	7.34	18.6	2	32	12.53	1.707	5.5	5.19
					2	40	13.26	1.807	6.1	5.92
					2	48	13.66	1.861	6.4	6.32
					1	32	16.49	2.246	8.4	9.15
					1	40	18.83	2.565	9.9	11.49
					1	48	21.19	2.887	11.2	13.85
16	3	32	3.25	18.6	3	32	7.04	2.165	8.0	3.79
					3	40	7.73	2.379	9.1	4.48
					3	48	8.33	2.563	9.9	5.08
					2	32	12.53	3.855	14.4	9.28
					2	40	13.26	4.081	15.1	10.01
					2	48	13.66	4.203	15.4	10.41
					1	48	21.19	1.949	6.9	10.32
16	2	40	7.54	18.6	2	40	13.26	1.759	5.8	5.72
					2	48	13.66	1.811	6.1	6.12
					1	40	18.83	2.497	9.6	11.29
					1	48	21.19	2.810	10.9	13.65
16	3	40	3.40	18.6	3	40	7.73	2.271	8.5	4.33
					3	48	8.33	2.446	9.4	4.92
					2	40	13.26	3.896	14.6	9.86
					2	48	13.66	4.012	14.9	10.26

(column 9) and then to seek out the rate of value increase in compound-interest tables for $(1 + r)^{10}$ (column 10) which equates the compound-interest formula.

Thus, in our example of a 16-inch d.b.h. vigor I butt-log grade 2 yellow-poplar, 24-foot merchantable height, we determined that the rate of value increase over the 10-year period could vary from 5.7 to 11.5 percent; and we could expect dollar value increases ranging from $4.74 to $12.49, depending on changes in merchantable height and quality. Considering diameter growth alone, we could expect a rate of value increase of 5.7 percent. Diameter growth plus an increase of one log in merchantable height would result in an estimated 7.7 percent rate of value increase. When quality was increased one grade, the greatest gains in rate of value increase were achieved, ranging from 8.0 to 11.5 percent.

Throughout the development of the rate of value increase it was constantly apparent that the final tables that resulted would not depict the situation for all users of these tables and that the rate for any specific tree was only an estimate. There are several reasons why these calculations are merely estimates. In producing the quality index, a major factor in variation is the assumption of lumber grade recovery of 4/4 factory-grade lumber. Few, if any, mills would duplicate this recovery. They might increase the value of products recovered by producing different thicknesses or other products.

The use of a specific set of conversion costs (table 2) is but another necessary generalization that may or may not fit the existing situation for a timber stand or logging crew. The timber stand may be readily accessible or very remote, and average figures for conversion costs would not fit the situation. Similarly, a logging crew could be very efficient and well equipped or they could be inefficient and poorly equipped, and either factor would cause wide variations from these average conversion costs. Furthermore, market prices for lumber vary widely by locality and season, depending on supply and demand. Variations in price will cause wide variations in the rates of value increase.

For the above reasons any presentation of exact rates of value increase would be illusory and could possibly lead to improper use. Thus tables 4 and 5 show the rates of value increase as a range of rates for ranges of sites. The person using this information need only determine the diameter and vigor of the tree to determine the range of rates of value increase due only to growth that can be expected in the next 10 years. If he estimates that the tree will improve in quality due to a higher butt-log grade class during this period, he can look for a value increase rate due to growth and quality increase.

Table 4.—*Expected rate of value increase for yellow-poplar trees*[1]
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase[2]		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
12	—	—	—	27-32[3]	24-30[3]	22-27[3]
14	7-11	5-8	3-6	8-24[3]	6-22[3]	4-19[3]
16	5-9	4-6	3-5	7-17[3]	6-15[3]	4-13[3]
18	4-7	3-5	2-4	6-13[3]	5-11[3]	4-9
20	4-6	3-4	1-3	6-11	5-9	4-8
22	3-5	2-4	1-3	5-10	4-9	4-8
24	2-4	2-3	1-2	4-9	4-8	3-7
26	2	1-2	1	4-7	4-7	3-8
28	2	1	1	([4])	([4])	([4])
30	1-2	1	1	([4])	([4])	([4])
32	1-2	1	1	([4])	([4])	([4])

[1] Based on 4/4 factory-grade lumber recovery. These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2] The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o. For this reason, butt-log grade 3 logs have not been considered in the estimates due to growth only.

[3] The high rates of value increase in the 12- to 18-inch diameter classes are due to two factors: the butt-log grade 3 trees becoming positive in present value, and the butt-log grade 3 trees improving to butt-log grade 2.

[4] No quality increase from trees larger than 26 inches.

Some Interpretations of the Rate-Of-Value-Increase Concept

Diameter growth, increase in merchantable height, and improvement in quality occur singly or in combination to add value to the tree and hence the stand. This value increment is the basis for determining the possible financial returns as measured by the rate-of-value-increase concept.

As we said earlier, the concept does not provide the complete solution for the financial investment in timber growing. Such a solution encompasses a much greater realm involving land costs and owner objectives, to name but a few, and is beyond the scope of this paper.

Though the rate-of-value-increase concept does not accurately reflect the situation for every logging chance and every sawmill,

Table 5.—*Expected rate of value increase for beech trees*[1]
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase[2]		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
14	([3])	([3])	([3])	([3])	([3])	([3])
16	2-15	1-12	0-10[4]	24-37[5]	23-34[5]	22-33[5]
18	2-8	0-5[4]	0-5[4]	11-46[5]	9-43[5]	9-42[5]
20	2-4	1-3	0-2[4]	7-14	6-13	5-12
22	2-3	1-2	1-2	5-11	4-10	4-10
24	1-2	1	1	4-9	3-8	3-8
26	1	1	1	3-8	3-8	3-8
28	1	0-1	0	3-8	3-8	2-8
30	1	0-1	0	3-8	2-7	2-7
32	1	0	0	2-7	2-7	2-7

[1]Based on 4/4 factory-grade lumber recovery. These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2]The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o. For this reason butt-log grade 3 logs have not been considered in the estimates due to growth only.

[3]Negative rate.

[4]Low value due to increase in ½-log height, where upper ½-log has minus value due to conversion costs.

[5]The high rates of value increase in the 16- and 18-inch diameter classes are due to two factors: the butt-log grade 3 trees becoming positive in present value, and the butt-log grade 3 trees improving to butt-log grade 2.

it does reveal certain generalities about the financial development of a tree:

Rate of tree earning power decreases with increasing tree size.—This is well illustrated in tables 4 and 5, which chart the gradual reduction of the expected rate of value increase as larger diameter trees are considered. Thus a 14-inch d.b.h., vigor I yellow-poplar, has the potential of earning during the next 10 years an annual rate as high as 11 percent, based on growth alone, and 24 percent based on growth and possible quality improvement. On the other hand, a 26-inch d.b.h. yellow-poplar of the same vigor class will earn about 2 percent in growth alone and a maximum of 7 percent if grade improvement occurs.

We must emphasize that the preceding discussion refers to the *rate* of tree earning power and not to earning power itself. Whereas the smaller diameter tree has higher expected rates of value increase (table 6, column 10) than larger diameter trees, the latter provide greater dollar value increase (table 6, column 11). Therefore earning power can be analyzed on the basis of either rate or dollar increase, depending upon the timber owner's objectives.

Improvement in log quality greatly increases earning power in both rate and dollar value.—As trees develop, many of them can be expected to improve in quality. It is important that the potential for quality improvement be recognized in selecting trees to remain in the stand. For example, an 18-inch vigor-I yellow-poplar can have a rate of value increase of 7 percent due to growth alone (table 4). However, if a log-grade improvement takes place in the next 10 years, a rate of value increase of as much as 13 percent annually can be expected.

Table 6 also illustrates the dollar gains to be made by improvement in quality. For example, a 14-inch vigor-I yellow-poplar, butt-log grade 2 with a 16-foot merchantable height, will have a future value increase of $2.82 due to growth alone. However, if an improvement in quality occurs, the same tree will have an increase of $3.66. This amounts to a gain of $0.84 due

Table 6.—*A comparison of the rates of value increase and the dollar-value increase of some 14- and 26-inch d.b.h., vigor I, yellow-poplar trees*

Present				Future						
D.b.h.	Butt-log grade	Log height, feet	Conversion value, dollars	D.b.h.	Butt-log grade	Log height, feet	Conversion value, dollars	Ratio V_n/V_o	Percent rate of return	10-year value increase, dollars
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
14	2	16	3.03	16.8	2	16	5.85	1.93	6.8	2.82
					1	16	6.69	2.21	8.3	3.66
	3	16	.98	16.8	3	16	2.72	2.77	10.7	1.74
	2	24	3.98	16.8	2	24	7.64	1.92	6.8	3.67
					1	24	9.32	2.35	8.9	5.35
	3	24	1.26	16.8	3	24	3.62	2.88	11.2	2.36
	2	32	4.43	16.8	2	32	8.67	1.96	6.9	4.23
					1	32	11.38	2.57	9.9	6.95
	3	32	1.36	16.8	3	32	4.20	3.10	12.0	2.85
26	2	16	24.27	28.1	2	16	29.38	1.21	1.9	5.11
					1	16	36.59	1.50	4.2	12.32
	3	16	16.62	28.1	3	16	20.69	1.24	2.2	4.07
	2	24	31.16	28.1	2	24	38.64	1.24	2.2	7.48
					1	24	50.15	1.61	4.9	18.99
	3	24	21.98	28.1	3	24	28.03	1.27	2.5	6.04
	2	32	36.73	28.1	2	32	45.68	1.24	2.2	8.94
					1	32	62.05	1.69	5.4	25.32
	3	32	26.80	28.1	3	32	34.25	1.28	2.5	7.45

to quality improvement alone. Had this improvement occurred on a 26-inch butt-log grade 2 yellow-poplar, the gain would have amounted to $7.21. Thus again, with increasing tree size we find a trend toward lower rates of value increase but higher dollar returns.

Many small sawtimber trees with grade 3 butt-logs have low or even negative stumpage values. Though these low-grade trees may earn a high interest rate, the actual monetary gain is small and stand earning power for a forest of such trees would be low. When such trees are vigorous and are low grade only because *they are small,* they may be retained in the stand; but if they do not have potential for grade improvement they should be removed as soon as possible.

We repeat: that the probability of grade improvement decreases with increasing tree size. However, this tendency varies appreciably in the two species considered. Generally, the likelihood of future grade improvement for trees of the larger sizes in managed stands in which improvement cuttings (or thinnings) have been made would be slight because the best stems would have been favored in previous markings *(Trimble 1965).* In managed stands the financial-maturity diameter is lower than in unmanaged stands.

Trees with greater merchantable height have, on the average, slightly higher earning rate potential if vigor class, butt-log grade, and site quality are the same.—The effect of log-height increase in a tree may increase the earning rate or it may decrease it. If the volume added in height growth has a positive conversion value, the percent of return will increase; however, if it has a negative value—as small grade 3 logs do—the percent of return will decrease. In general, log-height increases will be limited to the smaller trees; and the volume added will decrease tree earning power over the 10-year period even though the tree may have potential for increasing earning power over a longer period. In comparing two trees with similar characteristics except for height, the tree with the greater merchantable height will increase more in value in a given time.

Marking Guides

Marking guides, based on tree earning power—and to some extent on generally recognized marking principles—are suggested as: (1) guides for selection cutting under uneven-aged systems, for improvement cutting in previously unmanaged stands, and for sawlog thinnings in stands managed under an even-aged system; and (2) guides for setting average tree diameters for harvest cuttings (rotation tree size) under even-aged management.

For this latter use, these guides can be assumed appropriate only for stands now at or nearing financial maturity. Extending their use beyond 10 to 15 years in the future is risky because probable changes in markets and utilization practices may completely alter rates of return.

Because most hardwood stands that will be cut in the near future are some combination of immature, previously unmanaged, or very lightly managed stands, the guides will be most useful in marking for partial cutting—probably in improvement cuttings and thinnings in immature stands that will eventually be clearcut under some even-aged system. Used in this way, marking guides must be considered in conjunction with residual stocking guides.

Partial Cutting

In both species, the trees that should be discriminated against are: (1) culls and near culls, (2) extremely rough trees with butt-log grade 4, (3) vigor IV trees of any sizes, (4) any trees over 15 inches with butt-log grade 4.

For both species, the trees to be favored as leave trees are: (1) those with imminent butt-log grade improvement; (2) vigor I trees over vigor II and III, and vigor II over vigor III; (3) trees of greater merchantable length over trees of less merchantable length, other factors being similar; and (4) smaller sawlog trees over larger sawlog trees of similar grade and vigor classes.

Rotation Size

The rate-of-value-increase concept can also be used to determine rotation size in even-aged stands after proper consideration is given to silvicultural and management needs. These guides,

presented separately by species in tabular form (tables 7 and 8), are given for three interest-rate objectives—2, 4, and 6 percent. (The diameters given are average stand diameters.)

For example, in choosing a 2-percent interest-rate objective, say where multple-use forest values are involved, financial maturity for yellow-poplar would vary between 20 inches for vigor III trees to 27 inches for vigor I trees. For beech, the range would be between 19 and 23 inches d.b.h. In managed stands practically all final crop trees would be vigor I and II trees, and financial maturity would lie between the sizes indicated for these two vigor classes.

A commercial enterprise where timber values alone are important might choose a 6-percent interest rate. In this case, the financial maturity d.b.h. would be considerably lower for both species.

Though these data are presented as guides for harvest cuttings under even-aged management, they can serve also as guides to partial cutting where no grade improvement is in prospect for the tree in question. We emphasize that the diameters in these tabular guidelines are based on value increases due to growth rate alone and should be adjusted upward where potential log-grade increase is involved.

The blanks in the tables mean that the rate of interest cannot be obtained with any size sawtimber trees of butt-log grade 3.

Table 7.—*Yellow-poplar d.b.h. for financial maturity based on value increase determined by growth rate alone. Based on trees with butt-log grades of 1 and 2*[1]

Vigor class	For return of —		
	2 percent	4 percent	6 percent
	Inches	*Inches*	*Inches*
I	27	21	17
II	24	17	14
III	20	14	—

[1]The d.b.h. given is the maximum that will earn the indicated interest rate in the next 10 years.

If marking is done in areas of tree populations that fall largely under the category of low vigor, poor site, and small diameter, then the general guides given under "Partial Cutting" should govern and specific d.b.h. limitations are unimportant.

As a word of caution in interpreting this table, users should keep in mind that the interest rates are based on trees already existing in a stand and on their projected value increase over the next 10 years. Costs of growing the stand to sawtimber size were not considered.

Table 8.—*Beech d.b.h. for financial maturity based on value increase determined by growth rate alone. Based on trees with butt-log grades of 1 and 2*[1]

Vigor class	For return of —		
	2 percent	4 percent	6 percent
	Inches	*Inches*	*Inches*
I	23	19	17
II	20	17	16
III	19	16	—

[1]The d.b.h. given is the maximum that will earn the indicated interest rate in the next 10 years.

■

Appendix

DEFINITION OF VIGOR CLASSES

Vigor I.—A tree in this vigor class has a large, healthy, full crown in a dominant or co-dominant position. Half the crown or more is exposed to direct sunlight. The crown is typically dense, with no evidence of disease or mechanical injury. The bark and twigs have good color.

Vigor II.—A tree in this vigor class has a fair-size crown in a co-dominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and less perfect than that of a vigor I tree. This class may also include a large-crowned or dominant tree that otherwise fails to meet the requirements for vigor I.

Vigor III.—A tree in this vigor class has a medium to small crown of intermediate position. Only the top is exposed to direct sunlight. The crown may be open, with some dead or broken limbs. This class also includes trees with fair to large crowns, in a co-dominant position, but cannot meet requirements for vigor I and vigor II. It may also include overtopped trees of a tolerant species that have dense crowns of good color.

Vigor IV.—A tree in this class usually has a small crown in an overtopped position. This class includes all living trees that fail to meet the requirements of the higher vigor classes.

Table 9.—*Tree quality index for yellow-poplar trees*

Tree d.b.h. (inches)	Merchantable height in feet to an 8-inch d.i.b. top						
	16	24	32	40	48	56	64
			BUTT-LOG GRADE 1				
16.0	0.788	0.773	0.759	0.745	0.730	0.716	0.701
18.0	.818	.804	.789	.775	.760	.745	.731
20.0	.848	.834	.819	.805	.790	.775	.761
22.0	.878	.864	.849	.835	.820	.805	.791
24.0	.908	.894	.879	.864	.850	.835	.821
26.0	.938	.924	.909	.894	.880	.865	.851
28.0	.968	.954	.939	.924	.910	.895	.881
30.0	.998	.983	.969	.954	.940	.925	.911
32.0	1.028	1.013	.999	.984	.970	.955	.941
			BUTT-LOG GRADE 2				
14.0	0.731	0.698	0.666	0.633	0.601	0.568	0.536
16.0	.746	.714	.681	.649	.616	.584	.551
18.0	.762	.730	.697	.665	.632	.600	.567
20.0	.778	.745	.713	.680	.648	.616	.583
22.0	.794	.762	.730	.697	.665	.632	.600
24.0	.809	.777	.745	.712	.680	.647	.615
26.0	.825	.793	.760	.728	.695	.663	.630
28.0	.841	.808	.776	.744	.711	.679	.646
30.0	.857	.824	.792	.759	.727	.694	.662
32.0	.873	.840	.808	.775	.743	.710	.678
			BUTT-LOG GRADE 3				
12.0	0.528	0.515	0.503	0.490	0.478	0.466	0.453
14.0	.548	.535	.523	.510	.498	.485	.473
16.0	.568	.555	.543	.530	.518	.505	.493
18.0	.587	.575	.562	.550	.538	.525	.513
20.0	.607	.595	.582	.570	.557	.545	.532
22.0	.627	.615	.602	.590	.577	.565	.552
24.0	.647	.634	.622	.610	.597	.585	.572
26.0	.667	.654	.642	.629	.617	.604	.592
28.0	.687	.674	.662	.649	.637	.624	.612
30.0	.706	.694	.682	.669	.657	.644	.632
32.0	.726	.714	.701	.689	.676	.664	.651

Table 10.—*Tree quality index for beech trees*

Tree d.b.h. (inches)	Merchantable height in feet to an 8-inch d.i.b. top					
	16	24	32	40	48	56
			BUTT-LOG GRADE 1			
16.0	0.789	0.732	0.674	0.617	0.559	0.502
18.0	.823	.766	.708	.651	.593	.536
20.0	.858	.800	.742	.685	.627	.570
22.0	.892	.834	.777	.719	.662	.604
24.0	.926	.868	.811	.753	.696	.638
26.0	.960	.902	.845	.787	.730	.672
28.0	.994	.936	.879	.821	.764	.706
30.0	1.028	.970	.913	.855	.798	.740
32.0	1.062	1.005	.947	.890	.832	.775
			BUTT-LOG GRADE 2			
14.0	0.550	0.535	0.521	0.506	0.491	0.476
16.0	.571	.556	.541	.526	.512	.497
18.0	.591	.576	.562	.547	.532	.517
20.0	.612	.597	.582	.567	.553	.538
22.0	.632	.617	.603	.588	.573	.558
24.0	.653	.638	.623	.608	.594	.579
26.0	.673	.658	.644	.629	.614	.599
28.0	.694	.679	.664	.649	.635	.620
30.0	.714	.699	.685	.670	.655	.640
32.0	.735	.720	.705	.690	.676	.661
			BUTT-LOG GRADE 3			
12.0	0.495	0.477	0.460	0.442	0.425	0.407
14.0	.513	.495	.478	.460	.443	.425
16.0	.531	.513	.496	.478	.461	.443
18.0	.549	.531	.514	.496	.479	.461
20.0	.567	.549	.532	.514	.497	.479
22.0	.549	.567	.550	.532	.515	.497
24.0	.603	.585	.568	.550	.533	.515
26.0	.621	.603	.586	.568	.551	.533
28.0	.639	.621	.604	.586	.569	.551
30.0	.657	.639	.622	.604	.587	.569
32.0	.675	.657	.640	.622	.604	.587

10-YEAR D.B.H. GROWTH RATES

Table 11.—*Ten-year d.b.h. growth rate for yellow-poplar, in inches*

D.b.h. (inches)	Vigor I	Vigor II	Vigor III
12	2.9	2.1	1.4
14	2.8	2.0	1.3
16	2.6	1.9	1.2
18	2.5	1.8	1.2
20	2.4	1.7	1.1
22	2.3	1.7	1.1
24	2.2	1.6	1.0
26	2.1	1.5	1.0
28	1.9	1.4	.9
30	1.8	1.3	.8
32	1.7	1.2	.8

Table 12.—*Ten-year d.b.h. growth rate for beech, in inches*

D.b.h. (inches)	Vigor I	Vigor II	Vigor III
12	1.5	1.0	.09
14	1.4	.9	.8
16	1.3	.9	.7
18	1.2	.8	.7
20	1.1	.7	.6
22	1.0	.7	.6
24	.9	.6	.5
26	.8	.6	.5
28	.8	.5	.4
30	.7	.5	.4
32	.6	.4	.3

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The effect of XYLEM AGE on volume yield & sugar content of SUGAR MAPLE SAP

by Carter B. Gibbs

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RICHARD D. LANE, DIRECTOR

The Author

CARTER B. GIBBS, silviculturist, earned a bachelor's degree in 1950 and a master's degree in 1956 at the University of New Hampshire. In 1969 he received a Ph.D. degree from the New York State University College of Forestry at Syracuse. He has worked for private industry, the New Hampshire State Forestry Department, and the Bureau of Land Management of the U.S. Department of Interior. He joined the Forest Service in 1957 and has done research on the silviculture of southern pines in Texas, the silviculture of Appalachian hardwoods in West Virginia, and maple sap production techniques in Vermont, where he is now located at the Burlington research unit of the Northeastern Forest Experiment Station.

The effect of XYLEM AGE on volume yield & sugar content of SUGAR MAPLE SAP

THE QUESTION "How deep should a taphole be in a sugar maple tree to get the best production of sap and sugar?" has never been answered satisfactorily. Most studies of this question have been concerned mainly with volume of sap yield. Now the answer is being sought by looking at the age of the xylem—especially the outer layers where the greatest movement of sap and sugar occurs.

Studies of differences in sap flow from tapholes of various depths were made as early as 1895. Wood (*1895*) concluded that the then common practice of tapping to a depth of 1 inch, in the belief that most of the sap came from outer wood, was erroneous. He recommended tapping to depths of 4 or 5 inches. Morse (*1895*) found that deeper tapholes flowed longer than shallow tapholes. In more recent times, Cope (*1949*) used an instrument that separated yields from 2-inch and 4-inch depths in the same taphole; he showed that as much as one-third of the potential flow is lost by tapping to a 2-inch depth as opposed to tapping to a 4-inch depth. Morrow (*1963*), in a test of 2-inch and 3 1/2-inch holes, found that the deeper tapholes yielded

significantly greater amounts of sap in two out of the seven seasons tested, and that there was a tendency toward more flow from the deeper taps in all years.

Although deep tapping apparently increases yields, there is a limit to the increases that can be obtained this way. Jones, Edson, and Morse (*1903*) showed that sap volume yields decreased after the optimum depth of 3 inches was reached. They also showed that sap-sugar content decreased as taphole depth increased. Herbert (*1923*) reported that nothing is gained by tapping more than 2 inches deep. In a comprehensive study of sap flow, Robbins (*1960*) compared yields from 2-, 4-, and 6-inch taps and found significantly greater yields from the 4-inch tapholes than from either of the other depths.

All this previous work was oriented toward yield as a function of taphole depth; none of it dealt with the basic problem of identifying the high-sap producing areas of the xylem. It is known that the sap-bearing tissue of the maple consists primarily of vessel cells in the xylem (*Marvin 1958*). However, the xylem gradually becomes functionless as the tissues age, thus limiting sap flow to the outer portions of the wood (*Jones, et al. 1903*). This functional area no doubt varies from tree to tree, depending on vigor, size, and age.

At the Burlington, Vermont, research unit of the Northeastern Forest Experiment Station, a study was begun in 1966 in an effort to identify the portions of the xylem that produce the most sap and the sap with the highest sugar content. The study revealed that the greatest volume of sap comes from xylem that is about 35 years old, and that the sweetest sap comes from the young xylem just beneath the bark.

STUDY METHODS

Thirty-six vigorous sugar maple trees larger than 16 inches d.b.h. were each tapped once. Taphole depths ranging from 1 to 6 inches were assigned to trees at random until there were six trees in each of the following taphole depth classes: (1) 0 to 1 inch; (2) 1 to 2 inches; (3) 2 to 3 inches; (4) 3 to 4 inches; (5) 4 to 5 inches; and (6) 5 to 6 inches.

All tapholes were drilled in two stages. In the first stage, the hole was drilled through the bark and approximately 1/2 inch into the tree. Bark thickness was measured and added to the depth to be drilled. The taphole was then drilled to the prescribed depth plus bark thickness.

Flow from sections of the taphole that were not sampled—for example, the 0-to-4-inch section of a taphole scheduled to be sampled in the 4-to-5-inch depth—was blocked by a copper tube of the same diameter as the taphole (fig. 1). These tubes were coated with wax and inserted to the prescribed depth, thus leaving an open 1-inch sampling segment in each tree.

Figure 1.—For collecting sap flow from taphole depths greater than 1 inch, copper tubes were inserted into the taphole to stop the flow from lesser depths. Inset below shows the copper tube, fitted with a plastic spout.

For the 0-to-1-inch sampling depth, copper tubes larger than the taphole were placed over the taphole and driven through the bark to the wood (fig. 2). The bark at the bottom of the taphole was then sealed with hot wax to prevent sap leakage into the bark.

Drill shavings were removed from the taphole with a small wooden dowel, and a fresh paraformaldehyde pellet was placed in the 1-inch sampling segment. Metal buckets with covers were

Figure 2.—For collecting flows from the 0- to 1-inch depth, copper tubes were driven through the bark to the wood.

hung on nails inserted below the taphole for the sampling segments deeper than 1 inch. For the 0-to-1-inch depth, buckets were secured to the trees by a plastic bucket hook on a stainless steel wire (fig. 2).

Sap volume was measured 16 times during the season. Yield was recorded to the nearest 10 milliliters when the sap was liquid, and to the nearest 4 ounces when the sap was frozen. The previously determined bucket weights were subtracted from the total weight of the bucket plus frozen sap, and the sap weight was then converted to milliliters. Total seasonal sap-volume yield was calculated for each taphole.

Sap-sugar concentrations were recorded eight times during periods of moderate to heavy flow. Readings were made with a standard sap refractometer to the nearest 1/10 percent sap-sugar concentration. Average seasonal sap-sugar percentage was calculated for each taphole segment.

After the sap season, the age of the xylem at each sample depth was determined from an increment core taken just above or below each taphole. An increment borer was inserted to a depth greater than the taphole depth plus bark thickness. The total depth of the taphole and the innermost inch, the sampled area, were than marked on the core. The core was stained with phloroglucinol in the laboratory, and the total age of the taphole and the age at the beginning of the 1-inch sampling segment were determined with a binocular microscope.

The average age of each 1-inch taphole segment was computed by adding the total age of the taphole to the age at the beginning of the sampling segment and dividing the sum by two.

RESULTS AND DISCUSSION

General

Scatter diagrams of the data indicated that both relationships – volume yield over mean xylem age and sap-sugar percentage over mean xylem age – were curvilinear; and the data were subjected to computer analysis for curvilinear regression.

The relationship of number of annual rings in the 1-inch sampling segment to the volume yield and sugar percentage

variables was also considered. However, scatter diagrams indicated an unpatterned distribution of the variation in both variables.

Volume Yield – Mean Xylem Age Relationship

The regression model for volume yield-mean xylem age relationship followed a third-degree parabola

$$Y = b_0X + b_1X^2 + b_2X^3$$

where $\hat{Y} = 6296X - 129.21X^2 + 0.7056X^3$

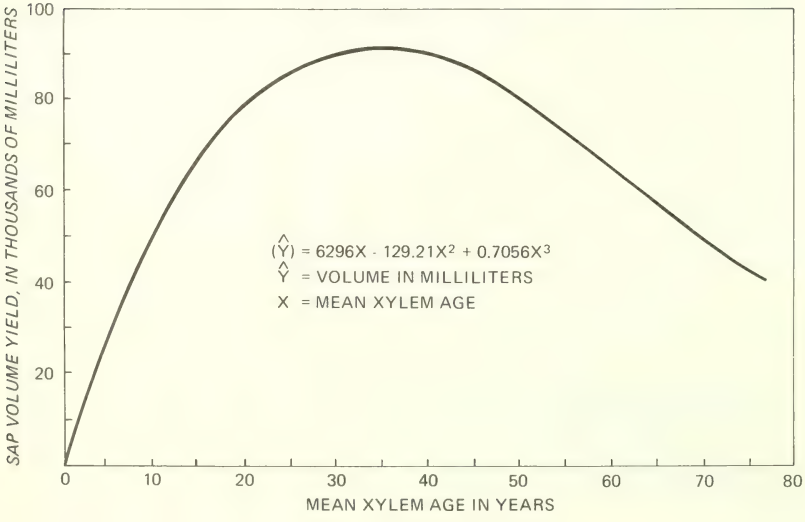
$\hat{Y}$ = Sap volume yield in milliliters.

X = Mean age of a 1-inch segment of xylem.

The multiple correlation coefficient (R^2) was 0.93, and the regression was significant at the 1-percent level. A graph of the computed curve is given in figure 3.

The curve indicates that the major area of sap movement during the sap season is in segments of the xylem that average 35 years old. Since no anatomical analysis was made of the

Figure 3.—Relationship of mean xylem age to sap volume yield.



xylem we can only postulate the reasons for this area of high productivity. It seems that chemical and morphological changes affecting sap movement must occur as the xylem increases in age. In the early years there may be a period of maturation before these tissues attain maximum transport efficiency. As the xylem ages, this efficiency apparently drops off, perhaps due to deposition of amorphous inorganic matter. Such obstruction is particularly true in sugar maple, according to Kramer and Kozlowski (*1960*).

To be useful to the average maple producer, mean xylem age must be related to taphole depth. To obtain an estimate of this relationship for the sugarbush used in this study, mean xylem age, total sap volume yield, and mean sap-sugar percentage were calculated for each depth sampled.

As expected, the high-yield areas bridged the 35-year average xylem age, indicating that tapholes at least 3 inches deep are needed to insure high productivity. Also, the accumulated volume yield (table 1) appear to make it worthwhile to drill tapholes as deep as 6 inches for maximum productivity.

However, the accumulated mean yields must be interpreted cautiously in view of previous studies that have shown that yield decreases with taphole depth greater than about 4 inches (*Robbins 1960*). A major difference between our study and previous studies is that copper tubes were used to block flow in certain taphole segments. Most investigators feel that some sap

Table 1.—Mean xylem ages, sap volume yields, and sap-sugar percentages, by 1-inch sampling depths

Segment depth	Mean xylem tissue age	Sap-sugar concentration	Sap volume yield	Cumulative yield totals
Inches	*Years*	*Percent*	*Gals.*	*Gals.*
0 to 1	6	3.9	8.5	8.5
1 to 2	16	3.2	20.0	28.5
2 to 3	27	2.9	23.5	52.0
3 to 4	37	3.1	20.9	72.9
4 to 5	54	3.5	18.4	91.3
5 to 6	64	2.8	14.6	105.9

absorption normally takes place in deep tapholes as a result of differences in temperature between inner and outer segments. Inner tissues react more slowly to temperature changes, either warming or cooling. Jones, Edson, and Morse (*1903*) concluded that the time of flow is associated with depth: outer segments of tissue flow first, then successively deeper tissues. Thus, the deeper tissues may absorb some of the sap flow from the outer tissues at certain times, and vice versa. Studies by Marvin (*1946*) have illustrated this absorption of sap by cold xylem tissue. In our study, sections of the taphole that might have absorbed sap were blocked by the copper tubes.

The accumulated mean volume yield of 1-inch segments was 105 gallons (table 1). This is much higher than would be expected from a single 6-inch taphole, which tends to support the theory that the copper tubes prevented absorption of sap in sections of the taphole at certain times. The high cumulative yield of 105 gallons may also be due partly to incomplete blocking of the unsampled taphole section by the copper tubes. Some sap may have moved along the copper tube from the blocked area into the sampling segment, thus inflating the yield of some or even all segments.

Another factor that must be considered in evaluating the results is that pressure and flows may be directional at any time during a sap-flow period. Sap moves either from below or from above the taphole as the result of the buildup of pressures in the tree roots or crowns (*Jones et al. 1903*). When the flows are from above, there is a possibility that the sap may pass through the taphole into tissues below and may be lost as yield. This condition may be less serious in short xylem segments than in deep tapholes where the range in temperatures and pressures are much greater.

All the factors of temperature, pressure, and directional flow appear to be closely interrelated; and they may affect yield from deep tapholes much more than yield from short segments of xylem or from shallow tapholes.

Sap-Sugar Percentage – Mean Xylem Age Relationship

The regression model for the sap-sugar percentage-mean xylem age relationship followed the logarithmic form

$$Y = b_o + \log_{10}\left(\frac{1}{X}\right)$$

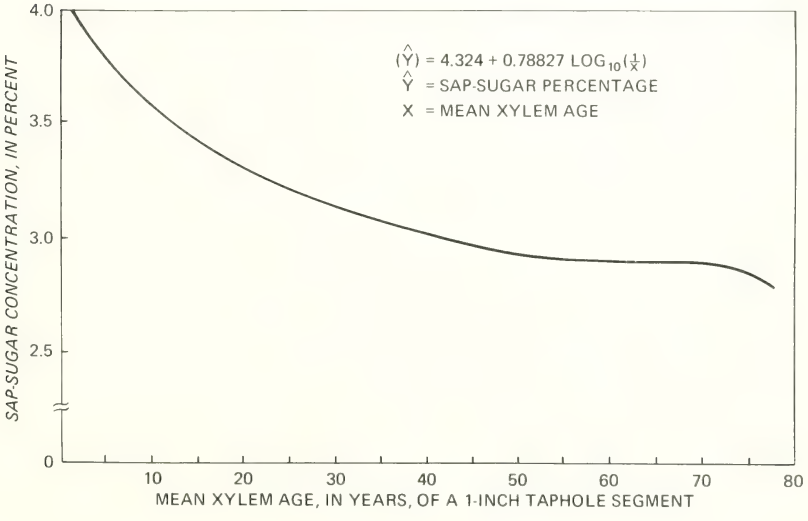
where $Y = 4.324 + 0.78827 \log_{10}\left(\frac{1}{X}\right)$

$\hat{Y}$ = Mean seasonal sap-sugar percentage.

$\hat{X}$ = Mean age of a 1-inch segment of xylem.

The multiple correlation coefficient (R^2) was low–0.43–but the regression was significant at the 1-percent level. The computed curve is shown in figure 4. The general shape of the curve indicates that either starch-to-sugar conversion or sugar transport is greatest near the bark–and perhaps both are greatest there. This seems logical because sucrose is utilized in metabolism as well as in growth processes concentrated in the cambial area. However, after a sharp initial drop, sap-sugar percentage declines

Figure 4.–Relationship of mean xylem age to sap sugar percentage.



slowly with increasing xylem age. Although their methods were strictly observational, Jones, Edson, and Morse (*1903*) found the same general trend.

The sap-sugar percentage curve has practical significance when sap-sugar percentage is to be used as a basis for breeding or thinning. Tapholes for tree-to-tree comparisons of sap-sugar concentrations should cover the same range of xylem age, or depth, because random taphole depths could mean differences in sap-sugar percentage resulting from xylem age affects rather than from inherited variations.

CONCLUSIONS

Seasonal sap volume yield and mean seasonal sap-sugar percentage are both correlated with the mean age of 1-inch segments of the xylem, and the relationships confirm the findings of others who worked solely with taphole depth.

Evaluation of the sap volume yield-xylem age relationship indicates that the accumulated mean yields of 1-inch segments are not a realistic expression of the total yield that could be expected from a single deep taphole. Other investigators have found that total yield from deep tapholes is less than that from average depths. In deep tapholes, where ranges in temperature and pressure can occur, parts of the xylem may be absorbing while other parts may be flowing. However, more research is needed before we can have an adequate understanding of the sap-flow process in the taphole.

Until further research more clearly identifies the depth of taphole that gives highest net yields, I recommend that tapholes be drilled just deep enough to include the area of maximum yield, which occurs in xylem aged 30 to 45 years. On most trees, this means that taphole depth should be 3 to 4 inches. This recommendation agrees with most of the conclusions from previous investigations.

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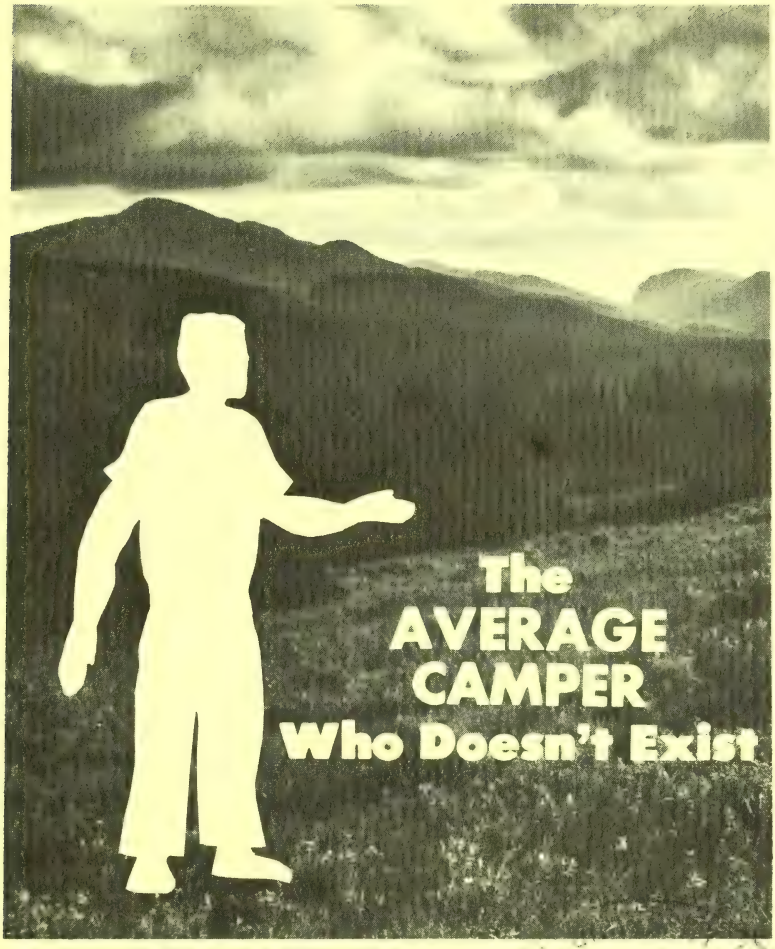

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The Author

ELWOOD L. SHAFER, JR. is a project leader for the Northeastern Forest Experiment Station's recreation research project at the New York State University College of Forestry at Syracuse University, Syracuse, New York. He holds Bachelor of Science and Master of Forestry degrees from Pennsylvania State University and a Ph.D. degree from the New York State College of Forestry. He joined the Northeastern Station in 1957.

INTRODUCTION

IN SURVEY STUDIES of campers, you can no more lump together data for different campgrounds than you can mate widgeons and wombats. Campers differ not only from campground to campground, but also at the same campground from month to month.

This was one major finding in a study made at five New York State campgrounds. In future surveys of this sort the campers sampled should be grouped according to monthly time periods, and the survey locations should be grouped by campgrounds that are similar in certain features.

If you study campers by sampling at random at several campgrounds, you may find that your data describe an "average" camper who simply does not exist. Such information is not good enough for recreation planners who need reliable information for making decisions.

A study was made in 1964 in northeastern New York State to determine if personal-interview data differ significantly among five campgrounds and three summer months. Campgrounds, months, or their interaction significantly affected the results of all 17 questions used in 1,140 interviews.

Results of this study should help strengthen the administrator's and researcher's awareness of the variation in camper characteristics and preferences. Some of the underlying causes of this variation, and its effect on future management and research, will be discussed later.

STUDY DESIGN

The five parks used were Fish Creek, Hearthstone Point, Rogers Rock, Rollins Pond, and Green Lakes. The parks differed considerably in physical site characteristics (table 1).

June, July, and August were used as three sampling periods. Climate, social, economic, and psychological factors were associated with different summer months. For example, water and air temperatures, number of insects, school vacations, and fishing success are associated with different periods of the summer. Total effect of any one factor does not begin and end exactly within each month. Nonetheless, a summer month represents a fairly uniform condition for many of the factors that affect camper behavior.

Table 1.—Physical site-characteristics of parks used for camper survey, 1964

Characteristics[1]	Fish Creek	Hearthstone Point	Rogers Rock	Rollins Pond	Green Lakes
Campsites ..... Number ..	379	246	301	257	202
Average distance between campsites ..... feet ..	58	45	64	84	45
Average slope of campground .... percent ..	2	13	12	18	4
Average density of vegetative screening between campsites[2] ..... percent ..	18	13	39	50	5
Average overstory density of all tree species[3] ..... percent ..	68	88	75	88	35
Average distance between a campsite and lake ... feet ..	18	578	272	148	2,680
Lake available for motorboats ..... acres ..	5,638	28,200	28,200	422	0
Additional lake available by canoe portage ..... acres ..	2,015	0	0	2,015	0

[1] Average values computed from measurements taken at 10 randomly selected campsites at each park. Other data obtained from the files of the New York State Conservation Department and the Central New York State Park Commission.

[2] As measured according to procedures described by Nord & Magill (*2*).

[3] As measured according to procedures described by Strickler (*7*).

Table 2.—Number of questionnaires that were partially or totally completed within each month, park, and replication

Month	Park	Replication	Total sampling frame available	Number of questionnaires obtained
June	Fish Creek	1	50	50
		2	51	51
	Hearthstone	1	37	37
		2	36	36
July	Fish Creek	1	68	66
		2	67	65
	Hearthstone	1	87	84
		2	91	88
	Rogers Rock	1	83	83
		2	84	84
	Rollins Pond	1	38	38
		2	36	36
	Green Lakes	1	78	78
		2	73	72
August	Fish Creek	1	45	45
		2	44	44
	Hearthstone	1	91	89
		2	96	94
		Total	1,155	1,140

Personal interviews were conducted during three months at Fish Creek and Hearthstone, and at all five parks during July. The questionnaire that was used is described in another study (*4*). Approximately every 4th camping party that registered at each park was personally interviewed, for a total of 1,140 interviews.

The other campers were used in a secondary phase of this study that compared personal interview results with results from three other user survey techniques (*4*).

Throughout the sampling procedures, completed questionnaires within each month-park category were assigned systematically each day to one of two replications. For example, if 24 camping parties were interviewed in 1 day at Fish Creek in June, every other interview was assigned to replication one, and the other 12 were assigned to replication two.

The total number of interviews within each park-month replication varied from 36 to 94 (table 2).

ANALYSIS

Each answer category for a question was analyzed separately. Analysis of variance (model I, fixed effects) was used to detect non-random differences among two parks and three months, and among five parks during July (*6*). Orthogonal comparisons (*8*) were used to compare results for June versus the average combined results for July and August; and also July versus August results (table 3). The Scheffé test (*3*) was used to make all 10 possible two-way comparisons between parks in July (table 4).

It was necessary to transform the data before analysis because the variances were not uniform at different times and places. For certain questions, the number of people in each answer category was expressed as a percent of total response to the question, and then was transformed (*6*) to arcs in$\sqrt{\text{percent} + 1}$ for analysis (table 3).

Answers to other questions involved a camping party's cost (X_j) of the trip or camping equipment. The transformed value analyzed within each park-month replicate, with sample size N_i, was

$$\sum_{j=1}^{N_i} \log (X_j + 1).$$

In these cases the analysis followed the procedure described by Snedecor (*6*) for a two-factorial experiment with disproportionate subclass numbers.

Irregular camper registration and departure patterns made it impossible to obtain an equal number of observations in all treatment combinations without biasing the results. Furthermore, different length-of-stay patterns among months and parks made it impossible to obtain *proportional* subclass samples. For example, the ratio between sample sizes for Fish Creek and Hearthstone was not equal throughout the three summer months (table 2):

$$101:73 \neq 131:172 \neq 89:183$$

Table 3.—An example of how data were analyzed among two parks and 3 months. Analysis of variance for the question: What was the most important reason you camped at the park? The value analyzed was the arcsin $\sqrt{\text{percent} + 1}$ of respondents in each category.

Source of variation	D.f.[1]	Campsites near water		Recommended by friends		Swimming and water sports facilities		Campground design and campground spacing		Landscape variability in surrounding areas	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Parks	1	3,989.90	458.08*	100.96	6.83*	5.97	0.33	9.21	0.55	1,442.98	149.84*
Months[2]	2	33.37	3.83	32.34	2.18	2.37	.13	2.23	.13	51.95	5.39*
1 vs. 2 + 3	1	11.57	1.32	63.32	4.28	4.71	.26	4.47	.27	78.75	8.17*
2 vs. 3	1	55.17	6.33*	1.38	.09	.02	.00	.00	.00	25.15	2.61
Parks x months	2	37.91	4.35	11.96	.80	19.31	1.07	81.50	4.93	.08	.00
Error	6	8.71	——	14.77	——	17.95	——	16.51	——	9.63	——

Source of variation	D.f.	Close to home		To be with friends camping at park		Tourist attractions near the park		Type and amount of trees and shrubs in park		Other reasons	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Parks	1	832.21	54.68*	0.04	0.01	105.91	33.62*	0.03	0.00	44.01	4.71
Months	2	23.20	1.52	21.17	4.75	64.61	20.47*	2.18	.38	12.28	1.31
1 vs. 2 + 3	1	35.76	2.34	31.71	7.11*	17.17	5.44	1.96	.34	20.97	2.24
2 vs. 3	1	10.64	.69	10.63	2.38	112.05	35.50*	2.40	.42	3.59	.38
Parks x months	2	50.94	3.34	3.67	.82	3.83	1.21	6.17	1.08	47.04	5.04
Error	6	15.22	——	4.45	——	3.15	——	5.67	——	9.33	——

[1] Degrees of freedom.

[2] June, July, and August are represented by 1, 2 and 3.

*Indicates significance at the 95-percent probability level.

Table 4.—An example of how data were analyzed among five parks during July. Analysis of variance for the question: How many years have you camped at this park? The value analyzed was the arcsin $\sqrt{\text{percent} + 1}$ of respondents in each answer category.

Source of variation	D.f.[1]	Never camped at the park before		Camped at the park for the last 2-5 years		Camped at the park for the last 6 or more years	
		Mean square	F	Mean square	F	Mean square	F
Parks[2] –	4	171.56	14.92*	106.03	6.61*	81.60	9.88*
1 vs. 2	4	100.3	8.75*	25.7	––	45.0	5.45*
1 vs. 3	4	32.2	––	5.3	––	17.2	––
1 vs. 4	4	2.5	––	17.8	––	25.6	––
1 vs. 5	4	18.5	––	19.3	––	72.2	8.75*
2 vs. 3	4	18.8	––	7.6	––	6.5	––
2 vs. 4	4	134.5	11.66*	86.5	5.41*	2.7	––
2 vs. 5	4	32.6	––	51.1	––	3.2	––
3 vs. 4	4	52.9	––	42.6	––	.8	––
3 vs. 5	4	1.9	––	19.2	––	18.9	––
4 vs. 5	4	34.6	––	4.6	––	11.8	––
Error	5	11.49	––	16.03	––	8.25	––

[1]Degree of freedom.

[2]Fish Creek, Hearthstone, Rogers Rock, Rollins Pond, and Green Lakes are represented respectively by 1, 2, 3, 4, and 5.

*Indicates significance at the 95-percent probability level.

VARIATION IN SOCIAL CHARACTERISTICS

Throughout the discussion of survey results, percentages and dollar values are presented graphically to assist in interpretation of results. Remember, however, that statistical inferences in these same graphs usually apply to some type of transformed data.

In the figures, percentages may not always add up to exactly 100 percent. Furthermore, percentage results from the two-factorial design may differ slightly from comparable data for the five parks in July. These discrepancies exist because the computer rounded values to the nearest whole percent.

Type of Camping Party

Over 90 percent of all parties interviewed at the five campgrounds were single families or groups of families. Approximately two-thirds of these families had children under 12 years of age and roughly one-third to one-half of the families had children between 12 and 18 years old. However, at this point the similarity among campers ends.

Type of Visit

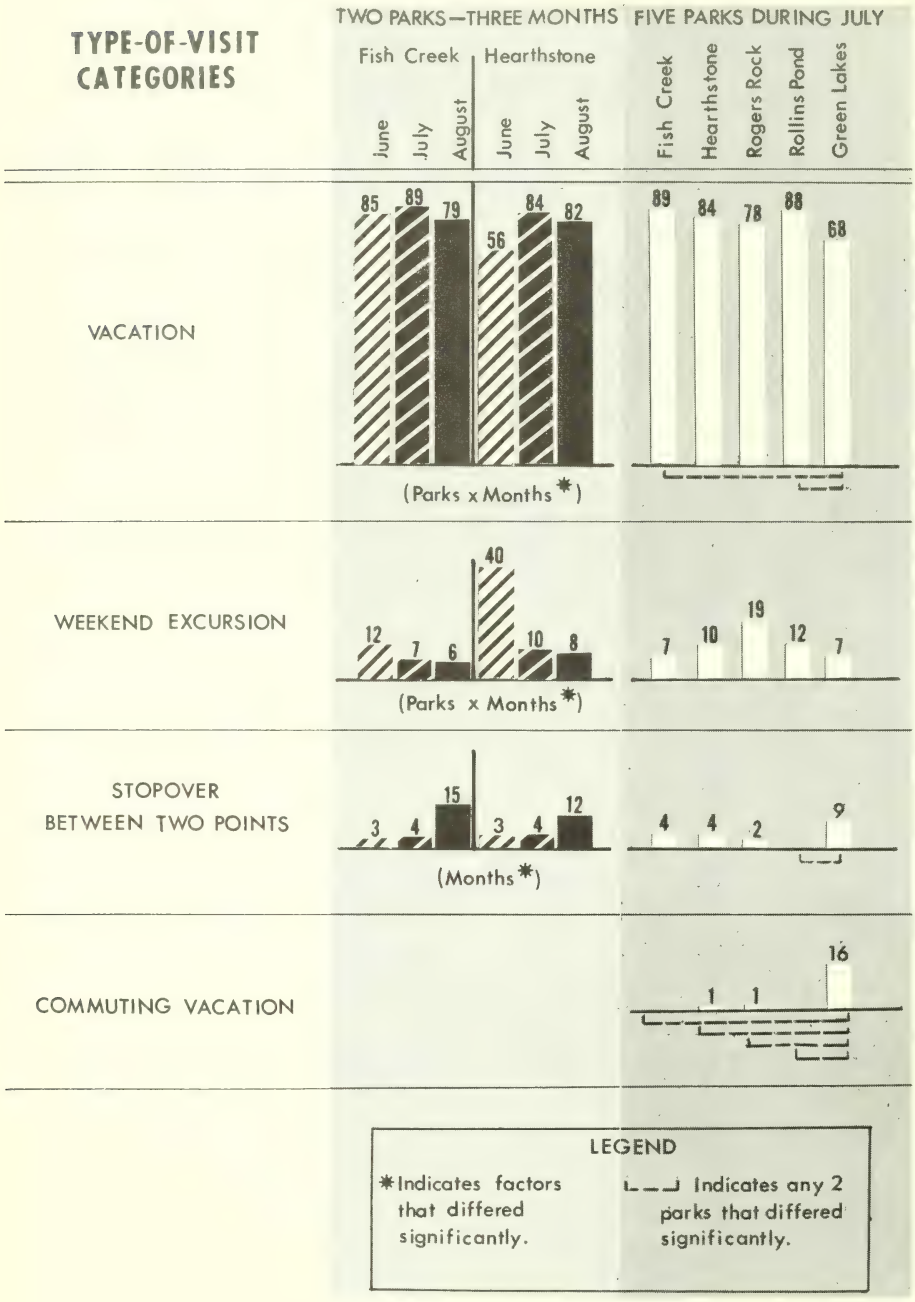
The percent of campers on vacation at Fish Creek and Hearthstone followed different patterns throughout the summer, and thus caused a significant park-month interaction. For example, vacationing campers at Hearthstone increased from 56 percent in June to around 82 to 84 percent in July and August. An opposite trend occurred at Fish Creek where 85 to 89 percent of the campers were on vacation in June and July, but this dropped to 79 percent in August. In July, slightly more than two-thirds of the camping parties at Green Lakes were on vacation. This differed significantly from the 89 and 88 percent at Fish Creek and Rollins Pond respectively (fig. 1).

A significant park-month interaction also occurred with those campers who used the parks for a weekend excursion (fig. 1).

Furthermore, Fish Creek and Hearthstone were used as stopover points significantly more often in August than during the rest of the summer. And almost 10 percent of the campers at Green Lakes were stopovers in July; however, this difference from the other parks may be because Green Lakes is only a 10-minute drive from an interstate throughway.

An interesting pattern was found at Green Lakes, where 16 percent of the family respondents camped while the father commuted daily to work in the nearby Syracuse metropolitan area (fig. 1).

Figure 1.—Type-of-visit patterns. Bars indicate percentage of camping parties in each category.



Length of Stay

Length-of-stay distributions were placed into four categories:

1. The *transient* camper who stayed 1 night.
2. The *short-stay* camper who camped 2 to 4 nights.
3. The *one-week* camper who stayed approximately 1 week—5 to 7 nights.
4. The *two-week* camper who camped 8 to 14 nights.

The proportion of short-stay campers at Fish Creek and Hearthstone differed significantly among months. For each of the other length-of-stay categories there either was a park-month interaction; or parks and/or months differed significantly.

Throughout the summer, Fish Creek had a greater proportion of 2-week campers than Hearthstone, whereas Hearthstone consistently had a greater proportion of 1-week campers (fig. 2).

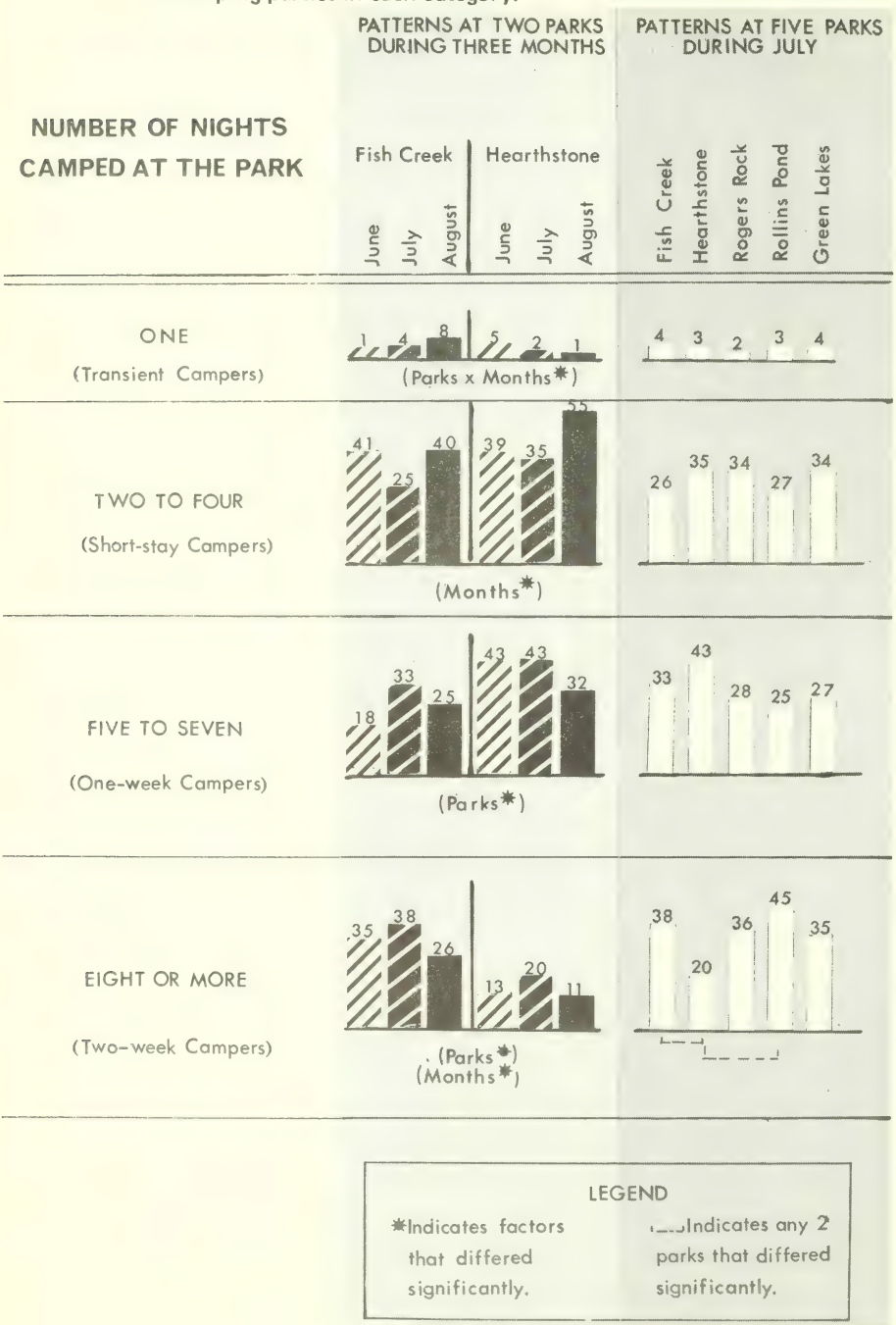
Rollins Pond, the most heavily wooded and most secluded campground of the five, had the greatest proportion of 2-week campers (45 percent). Hearthstone, with the least primitive surroundings of all the campgrounds, had the smallest proportion of 2-week campers (20 percent). At all parks, the 2-week camper accounted for an equal or greater amount of total days of campsite use than the transient or short-stay camper.

The multimodal length-of-stay patterns (fig. 2) at most parks show why it is not meaningful to use average length of stay per camping party, or a count of total number of campers, as an indication of use intensity. Rather, total number of user-days (U) throughout a season is more realistic. Where d_i is the length-of-stay for each of n total camping parties,

$$U = \sum_{i=1}^{n} d_i$$

For U to reflect the shape of the length-of-stay pattern, it may be necessary to multiply U by the proportion of 2-week campers. Other types of weighting are also possible.

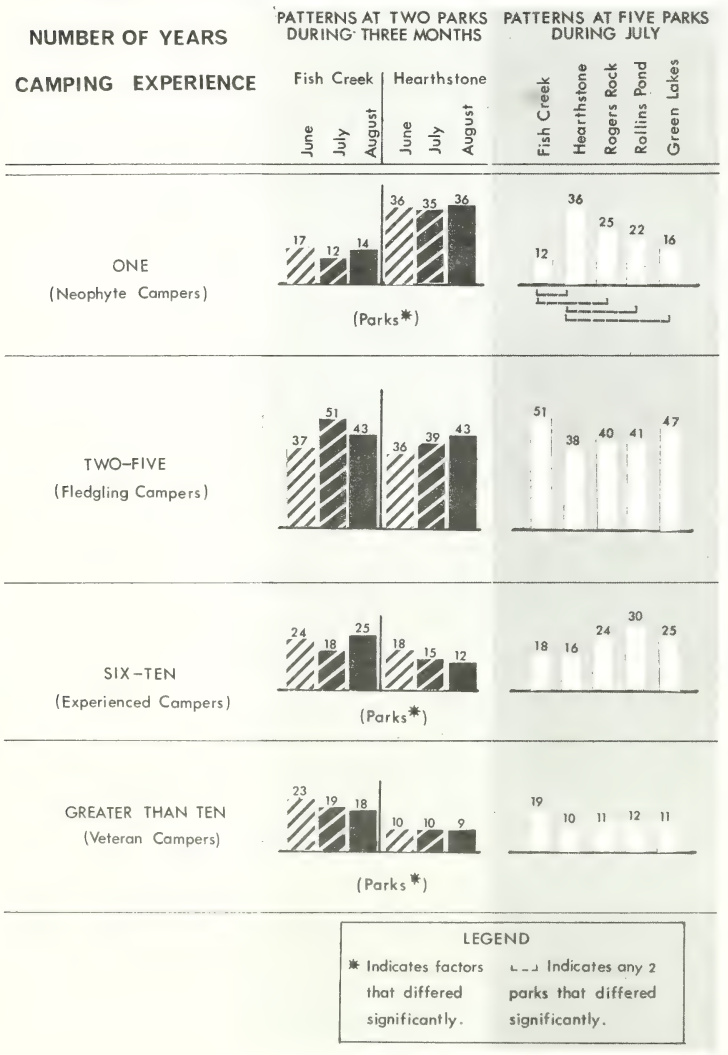
Figure 2.—Length-of-stay patterns. Bars indicate percentage of camping parties in each category.



Camping Experience

The number of years one camps reflects a certain degree of commitment to camping. The classification scheme described here attempts to segment this intensity of camping-commitment into four discrete categories:

Figure 3.—Camping-experience patterns. Bars indicate percentage of camping parties in each category.



1. The *neophyte* camper who was camping for the first time.
2. The *fledgling* camper who was gaining camping experience over a 2- to 5-year period.
3. The *experienced* camper who had camped for 6 to 10 years.
4. The *veteran* camper who had camped for more than 10 years.

Campers at Hearthstone differed from Fish Creek in three of these four categories. In July, Hearthstone had the greatest number of neophyte and the smallest number of veteran campers of all five parks. Fish Creek had just the opposite pattern (fig. 3). Neophyte and fledgling campers seem to like Hearthstone because it is surrounded by suburban conveniences and tourist attractions.

Repeat Visits

Preference for a park is reflected, at least partially, in the number of times one camps there. An effective classification for this type of behavior was:

1. The *initial* visitor who visited the park for the first time.
2. The *repeat* visitor who returned to the campground for 2 to 5 consecutive or intermittent years.
3. The *continuous* visitor who returned for 6 or more consecutive or intermittent years.

Campers at Fish Creek were distributed about evenly across all three of these categories. Significantly unlike this pattern, 66 1/2 to 80 percent of the campers at Hearthstone were initial visitors. Other parks in July also differed significantly within these various categories (fig. 4).

Other Camping Areas Used

The number of different campgrounds that individual camping parties use throughout their camping experience provides some indication of the variety of campgrounds they prefer.

Results of my inquiry about use of other campgrounds depended mainly on where, but not when, the question was asked. Fish Creek and Hearthstone differed significantly in

Figure 4.—Repeat-visitation patterns. Bars indicate percentage of camping parties in each category.

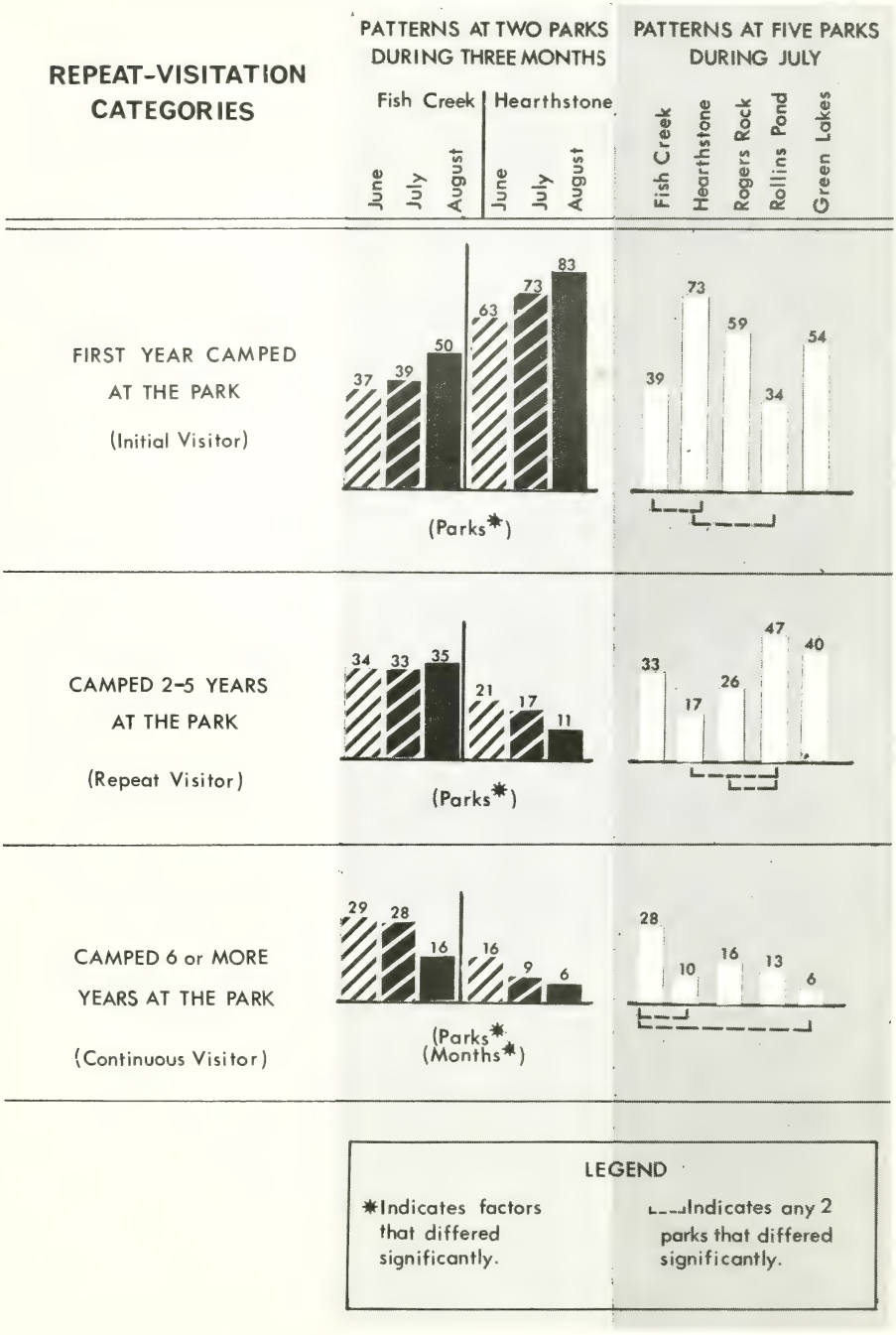
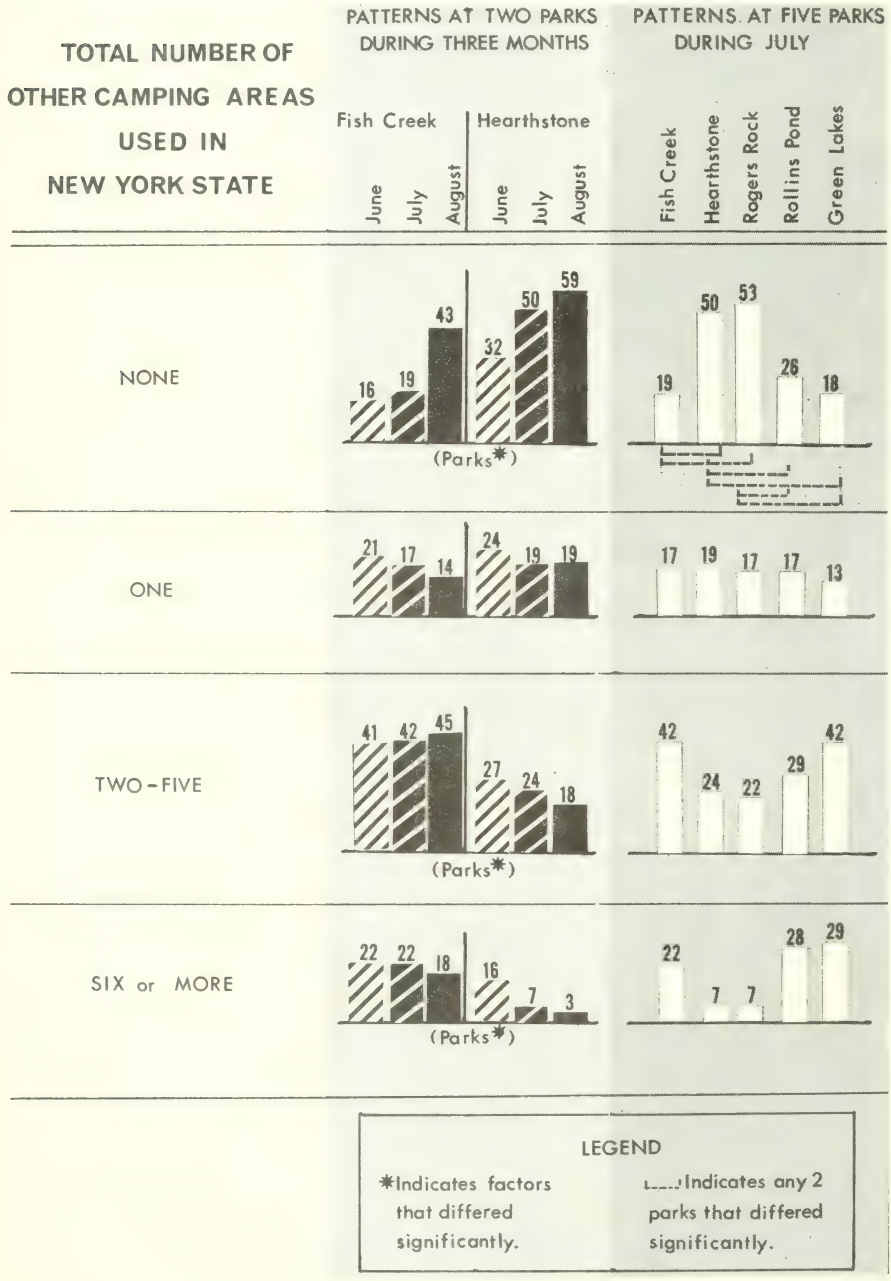


Figure 5.—Total number of camping areas that camping parties have used in New York State, other than the park in which the survey was conducted. Bars indicate percentage of camping parties in each category.



terms of the proportion of camping parties who used six or more, two to five, and no other campgrounds within New York State during their camping career. Many of the five parks differed greatly within the latter category during July (fig. 5).

Factors that Influenced the Visit

Between 92 and 100 percent of the respondents gave at least one reason for visiting the campground where they were interviewed. Reasons mentioned as most important were grouped into 10 categories (table 3). The seven reasons mentioned by 5 percent or more of the camping parties at a park during any one month were: campsite nearness to water, swimming and water-sport facilities, landscape variation surrounding the park, nearness to home, tourist attractions near the park, campground design, and recommendations by friends (fig. 6).

The primary reason usually differed significantly between parks and/or months (table 3). Usually, the predominant physical feature at each park was the major item that influenced a significant proportion of visits.

For example, at Fish Creek most campsites are located near a lake (table 1). So it is not surprising to find (depending on the month) that 46 to 59 percent of the respondents at this park, as compared with 1 to 16 percent at other parks, said nearness to water was the most important reason they camped there. This reason, together with recommendations by friends, influenced the *initial* visit to Fish Creek. Thereafter, campers returned annually because the campsites are near the lake.

At Green Lakes, on the outskirts of Syracuse, 37 percent of the respondents said they camped there because it was close to home. The proportion of campers who gave this reason at Green Lakes increased directly with the number of years they had camped there. At the other parks this reason was mentioned only by 1 to 14 percent of the campers interviewed, except during June at Hearthstone, where 28 percent gave this response.

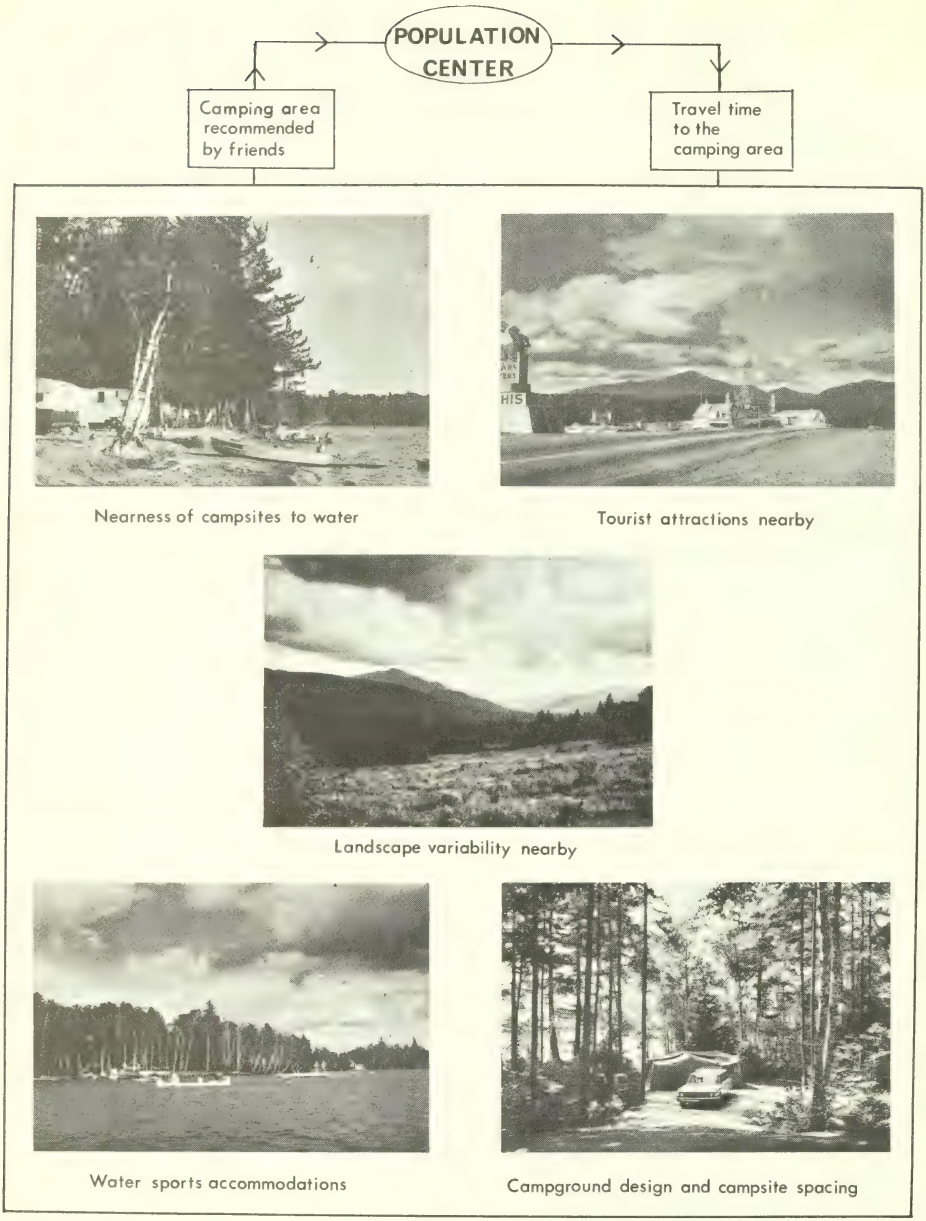

POPULATION CENTER
Camping area recommended by friends
Travel time to the camping area
Nearness of campsites to water
Tourist attractions nearby
Landscape variability nearby
Water sports accommodations
Campground design and campsite spacing

Figure 6.—Flow chart of the seven major factors that influenced use at five public camping areas in New York State. The relative importance of each factor differed significantly among the five campgrounds considered.

Rollins Pond campground is composed of a heavily wooded and secluded environment, unlike the other parks investigated (table 1). At this park, 32 percent of the respondents camped there because they liked the campground design and campsite layout. In comparison, only 1 to 12 percent of the campers at the other four parks gave this reason. Campground design influenced attendance at Rollins Pond, regardless of the number of years respondents had camped there.

Depending on the month, landscape variability accounted for a significant 21 to 32 percent of the response at Hearthstone. This park is surrounded by mountainous terrain and is located along the irregular shoreline of island-studded Lake George.

A substantial 22 percent of July campers visited the parks because they were recommended by friends. Thus we find a rub-off effect operating once campers return to their residences and describe their experiences to others. Clawson (*1*) inferred a trend of this type when he described a recollection phase of an outdoor recreation experience. The influence of friends ceases to be important after the initial visit.

Swimming and other water-sports facilities influenced 8 percent of the respondents to visit each park. However, swimming facilities are an important part of campground *design* at Fish Creek and Rollins Pond, where campers can swim and launch their boats a few feet from their campsites. The overall swimming facilities, other than the developed beaches at these two campgrounds, probably were included in the two major reasons for camping there—nearness to water and campground design.

In another study of *observed* use-intensities at Adirondack campgrounds, we found that measurements of the lake, swimming beach, and campground design can be used to mathematically describe use-intensity at a campground (*5*). These complementary results indicate that respondents in our study provided reliable and valid reasons for choosing a particular park.

Only a few camping parties mentioned that the type and amount of trees and shrubs in the park were important to the

visit. However, respondents may have considered vegetation as part of the dominant physical features of the landscape.

In summary, there are several factors that influence a person to camp at a specific park. How close it is to home is most important in some instances. Next, aesthetic features and nearness to water at the campground seem to be the prime factors. Finally, the decision to camp at a place for the first time can be most influenced by the comments of others who previously visited the area (fig. 6).

VARIATION IN ECONOMIC CHARACTERISTICS

Equipment Used

The proportion of campers who used tents, collapsible trailers, and house trailers was the same at Fish Creek and Hearthstone throughout the summer (fig. 7).

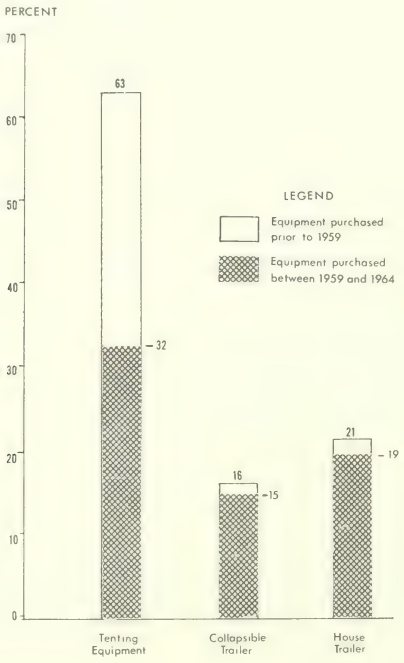
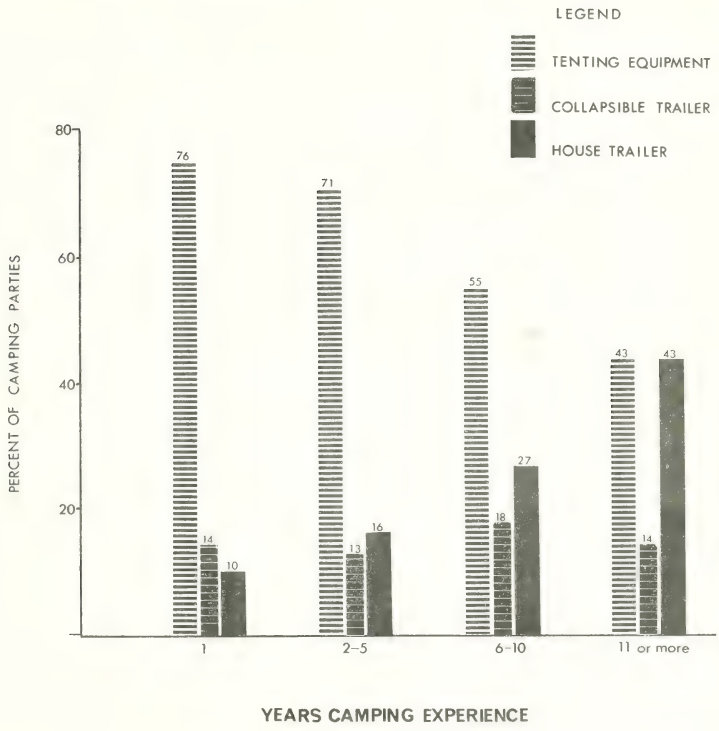


Figure 7.—Equipment used by campers. Bars indicate the percentage of camping parties having each type of equipment.

Figure 8.—Relation between camping experience and equipment-ownership patterns. Bars indicate percentage of camping parties in each category.



Tents were used by 63 percent of all the campers interviewed; 50 percent of these campers had bought their tents within the previous 5 years. Twenty-one percent of the respondents had house trailers and 16 percent had collapsible trailers. Most house and collapsible trailers were purchased within the previous 5 years, and this reflects a trend toward more comfortable and more convenient camping equipment (fig. 7).

Use of higher-priced camping equipment was significantly related to an individual's camping experience. Only 10 percent of the neophyte-campers (first-year campers), but more than 40 percent of the veteran-camper group (11 or more years camping experience) had house trailers (fig. 8).

Cost of Equipment

A significant park-month interaction, in terms of average *total* cost of equipment per camping party, occurred at Fish Creek and Hearthstone and four of the two-way comparisons among five parks differed significantly during July.

At the beginning of the camping season in June, the average total cost of equipment used at Fish Creek and Hearthstone was almost $1,000. During the high-intensity-use months of July and August, total equipment costs at Fish Creek remained close to $1,000, but equipment costs were 30 to 50 percent lower at Hearthstone (table 5).

The average cost of any one item covered a wide range of values, depending on where and when the data were obtained (table 5).

Park-month interactions were significant for five of the six items analyzed. Average cost of different equipment items also fluctuated significantly among the five parks in July.

The average cost of house trailers at Fish Creek ranged from $1,600 to around $1,900. This was 10 to 40 percent higher than the average cost of trailers used at Hearthstone (table 5). One explanation for these differences is that most campers at Fish Creek had more camping experience (fig. 3) and probably were more strongly committed to camping than campers at Hearthstone. Therefore, we would expect most campers at Fish Creek to have more expensive equipment.

Depending on the sampling location and period, average tenting-equipment costs ranged from $97 to $142, collapsible trailer costs varied from $483 to $727, and miscellaneous equipment costs ranged between $78 and $148 (table 5).

The average cost of boats used at Hearthstone varied between $637 and $837. This was 30 to 60 percent higher than boats used at Fish Creek. However, we might expect to find more expensive boats at Hearthstone because there is five times more lake area than at Fish Creek (table 1).

Table 5.—Average number of dollars invested during 1959-64 by the purchasers of camping and boating equipment.

Park	Month	House trailer	Collapsible trailer	Tenting equipment	Boat	Outboard motor	Other equipment	Average total investment per party
Fish Creek	June	$1,848	$630	$98	$338	$251	$123	$967
	July	1,948	598	108	496	223	122	987
	August	1,639	635	110	451	303	106	887
Hearthstone Point	June	2,010	727	142	762	137	78	1,051
	July	1,496	601	112	637	301	142	578
	August	1,320	615	97	837	453	148	551
Rogers Rock	July	1,494	615	98	1,040	356	141	733
Rollins Pond	July	1,352	502	99	249	188	117	623
Green Lakes	July	2,359	483	103	1,025	100	111	824

Cost of Camping Trip

During their visit, campers spent an average of $49 to $70 per party (table 6). Summer months significantly influenced the average total on-site expenditure per camping party at Fish Creek and Hearthstone. Between June and July, total average on-site costs rose 26 percent at Hearthstone, and 15 percent at Fish Creek (table 6). Also, for this same data, there were significant differences among the five parks in July.

Expenditure patterns were extremely variable between parks when the average total on-site cost was segmented into its five major components: food, entertainment, camping fees, gas and oil, and other miscellaneous expenses. Average money spent for lodging outside the campground was negligible (table 6).

Throughout the summer season, average camping-fee expenditures per camping party ranged between $7 and $13. As might be expected, average cost for camping fees and food followed approximately the same trend; from a low in June to a high in July, followed by a drop in August (table 6). These trends are related directly to the fluctuations in length-of-stay patterns at the parks (fig. 2). At Fish Creek, average food costs were the major on-site expenditure, ranging from $29 to $38 while those at Hearthstone averaged between $22 and $30 (table 6).

At both parks, money spent for entertainment rose from June through July, and this was the only thing that campers at Hearthstone spent more for—as much as 150 to 300 percent—than those at Fish Creek. Entertainment costs at Hearthstone undoubtedly were associated with the many tourist attractions in the Lake George area.

Significant differences between many of the parks during July, in terms of average on-site costs, provided further indications of the wide range of values that can be encountered, depending on where the data are gathered.

Income

Income distributions fluctuated significantly among months but were the same between parks. Ranges in income levels reported during the summer were as follows:

Table 6.—Average number of dollars spent per camping party while camping, 1964.

Park	Month	Entertainment	Camping fees	Food	Gas and oil	Other	Average total amount spent per party
Fish Creek	June	$ 5	$11	$29	$8	$3	$56
	July	7	12	38	8	3	68
	August	9	10	32	9	7	67
Hearthstone Point	June	12	8	22	7	—	49
	July	22	10	30	6	—	66
	August	22	7	24	6	—	57
Rogers Rock	July	16	11	37	6	1	70
Rollins Pond	July	5	12	36	8	2	64
Green Lakes	July	4	13	36	6	4	63

Income class (dollars)	*Percent of camping parties*
0 to 3,999	1 to 3
4,000 to 6,999	19 to 27
7,000 to 9,999	37 to 46
10,000 or more	27 to 34

About two-thirds to three-quarters of the respondents reported incomes of $7,000 or more.

VARIATION IN PREFERENCE FOR CAMPGROUND DESIGN

Number and Spacing of Campsites

Campground size did not seem to concern the respondents. The majority of campers at all parks sampled either were satisfied with the present campground size; or its size was not important to them. Thus expansion of present facilities may be satisfactory to most users.

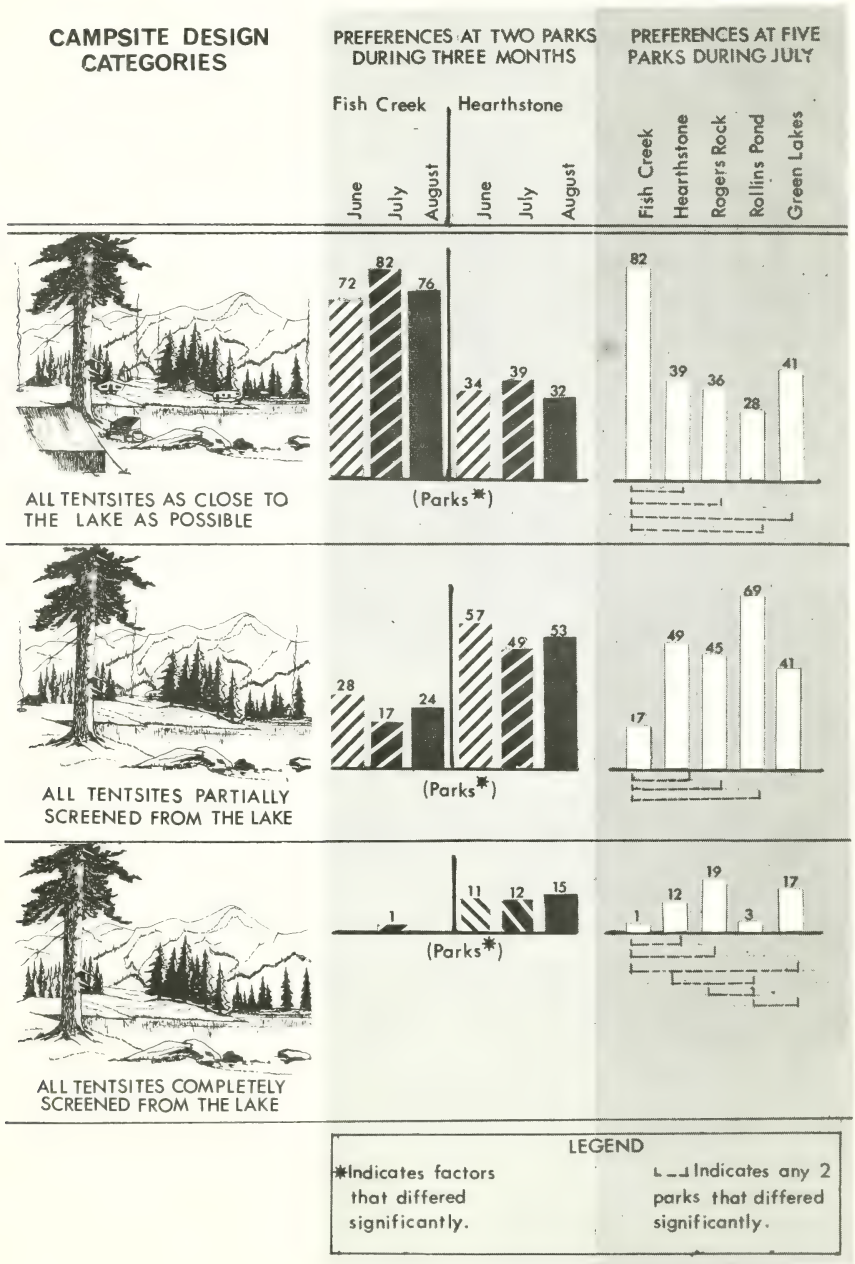
Depending on the individual park, average distance between campsites was 45 to 84 feet (table 1). Most campers (66 to 85 percent) felt that present campsite spacing was satisfactory, but another 14 to 28 percent preferred campsites twice as far apart as they are now.

Vegetative Screening

On-site conditions at individual parks seemed to influence preferences for vegetative-screening. At Fish Creek, where there was an 18-percent screening density (table 1), 43 percent of the campers in July desired sparse screening between campsites. In July at Rollins Pond, where there was a 50-percent screening density, none of the respondents chose the sparse-vegetation category.

Most people (85 percent) preferred either partial or very sparse screening between campsites. At most of the parks, understory vegetation density was sparse (table 1). Campers–

Figure 9.—Preference for campground design. Bars indicate percentage of camping parties in each category.



except those at Rollins Pond, the most primitive area—were not too concerned with the amount of understory vegetation available. In fact, the lack of screening in many cases presented the opportunity for campers to display camping and boating equipment. This in turn, may have afforded some degree of social prestige.

Nearness to Lake

On the average, 77 percent of the respondents at Fish Creek wanted to camp as close to the lake as possible, but only an average of 35 percent of the campers at Hearthstone wanted this (fig. 9). But again, on-site conditions seemed to influence questionnaire response. At Fish Creek, the average distance from a campsite to the lake was 18 feet, while at Hearthstone it was 578 feet (table 1). At the other extreme, Rollins Pond, where most campsites were almost completely screened from the lake by natural vegetation, and were located an average distance of 148 feet from the lake, 72 percent of the respondents wanted lakeshore vegetation either partially or completely undisturbed by campsites (fig. 9).

DISCUSSION

The months and parks studied do not represent random selections from a larger population. Therefore our results are restricted to the conditions investigated. However, in future surveys that deal with other summer seasons and campgrounds we can expect to find similar variation in the characteristics and preferences of the camping public.

In one phase of this study, survey data differed significantly 35 percent of the time between two parks, 24 percent of the time among three months, and 12 percent of the time in park-month interactions. In another phase, survey data differed significantly 38 percent of the time among five parks in July.

Therefore, if you plan to survey campers, you should stratify your sample beforehand by monthly intervals and similar campgrounds. Specifically, campgrounds within a strata should be approximately the same in terms of: number of campsites,

campground design, lake acreage available for boating, surrounding landscape, number of tourist attractions near the campground, and distance from population centers.

Otherwise, if you survey several campgrounds at random throughout a summer, your results will describe a nonexistent *average* camper who eventually can cause more management problems than your study intends to solve.

At present, one should relate management decisions and use-predictions to the physical and social environments that surround *individual* parks.

The same type of variation found among campers in this study probably exists also among fishermen, hunters, skiers, and other types of recreationists who use a wide variety of environments for their sport.

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A Silvicultural Guide for NORTHERN HARDWOODS in the Northeast

MAR 16 1970
SCI., TECH. & AGR. DIV.

by William B. Leak
Dale S. Solomon
Stanley M. Filip

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

The Authors

WILLIAM B. LEAK, silviculturist, received his forestry training at the State University of New York College of Forestry at Syracuse, where he earned his Bachelor of Science degree in 1953 and his Master of Forestry degree in 1956. He joined the Northeastern Forest Experiment Station in 1956, working first at the Station's research unit at Burlington, Vermont. For several years he was located at the Northeastern Station headquarters in Upper Darby, Pennsylvania. He is now project leader of the beech-birch-maple silviculture study at Durham, New Hampshire. Mr. Leak wrote the text and prepared the prescriptions for this guide.

DALE S. SOLOMON, associate mensurationist, joined the Northeastern Forest Experiment Station in June 1962 after earning his Master's degree in forestry from Yale University. He had earned a Bachelor's degree in forestry from The Pennsylvania State University in 1961. Since 1962 he has worked on the Station's beech, birch, maple silviculture project of the research unit located at Durham, New Hampshire. Mr. Solomon developed the stocking, growth, and yield data used in this guide.

STANLEY M. FILIP, silviculturist, received his forestry training at The Pennsylvania State University. After earning his Bachelor of Science degree in 1939, he was self-employed as a consulting forester in Wilkes-Barre for 2 years. He was also an industrial forester for the Wilkes-Barre Chamber of Commerce and a farm forester for the U.S. Forest Service and the Pennsylvania Department of Forests and Waters. He joined the Northeastern Forest Experiment Station in 1946, working first at the Station's research unit at Kingston, Pennsylvania. He has been assigned since 1954 to the Station's New Hampshire research unit, now located at Durham. Mr. Filip was responsible for much of the applied silvicultural and management information used in this guide, including use of chemicals in northern hardwoods.

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THE PURPOSE of this paper is to provide a practical guide to the management of northern hardwoods — principally beech, birch, and maple—in the Northeast. The guide was designed to provide the kind of information that is needed not only for long-term management planning, but also for short-term silvicultural prescriptions for specific timber stand conditions.

The guide is limited to silvicultural recommendations primarily for timber production. However, secondary forest uses such as recreation, water, and wildlife habitat are considered wherever pertinent.

The information in this guide applies directly to about 15 million acres of northern hardwoods in New England and New York, where northern hardwoods comprise nearly 35 percent of the commercial forest land area. Outside this area, the guide should be applied with caution.

The northern hardwoods support a thriving industry in the Northeast. These hardwood forests produce millions of cubic feet of veneer logs, sawlogs, millwood, and pulpwood each year. They are also the resource base for a lucrative and growing recreation industry, the habitat for a variety of game animals and other wildlife, and a protective cover for the watersheds that serve many cities and towns.

COVER TYPES AND SPECIES

The primary cover type in the Northeast is the northern hardwood or beech-birch-maple type (fig. 1). The important timber species are sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britton), and American beech (*Fagus grandifolia* Ehrh.). The important associated species, which occur in lesser amounts, are red maple (*Acer rubrum* L.), paper birch (*Betula papyrifera* Marsh.), white ash (*Fraxinus americana* L.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), balsam-fir (*Abies balsamea* (L.) Mill.), and red spruce (*Picea rubens* Sarg.).

The aspen-birch type commonly is associated with northern hardwoods in the New England - New York area. These are pioneer stands, characterized by a predominance of aspen (*Populus* spp.), paper birch, and gray birch (*Betula populifolia* Marsh.). Associates include red maple and other species found in the beech-birch-maple type.

Figure 1.—An uneven-aged northern hardwood stand.

Table 1.—*Silvical characteristics of the important species in the beech-birch-maple and associated types*

Species	Shade tolerance	Relative growth rate	Seeding frequency, good crops	Effective[1] seed dispersal	Minimum seedbed requirements	Sprouting vigor	Delayed germination
			Years	*Tree heights*			
Sugar maple	Tolerant	Medium	2–5	2–3	Light litter	Moderate	Possibly a small proportion
American beech	Tolerant	Medium	2–3	0–1	Light litter	Abundant root suckers	None known
Yellow birch	Intermediate	Slow to medium	2	2–4	Mineral soil or mixed mineral-humus	Very low	None known
Paper birch	Intolerant	Fast	2	2–4	Mineral soil or mixed mineral-humus	Moderate to low	None known
White ash	Intermediate	Medium to fast	3–5	2–3	Light litter	Moderate to high	Up to three-fourths germination second spring
Red maple	Intermediate	Medium to fast	1	2–3	Light litter	Very high	Small proportion germinate second spring
Aspen	Intolerant	Fast	4–5	—	Continuous moisture	Abundant root-suckering	None
Red spruce	Tolerant	Medium	3–8	2–4	Moist humus or mineral	—	None known
Eastern hemlock	Tolerant	Medium	2–3	2–4	Moist humus or mineral	—	None known

[1] Effective seed dispersal means that roughly 50 to 75 percent of the seed falls within the given distance.

The spruce-fir type also is associated with northern hardwoods at elevations near sea level in far northern New England and at elevations above about 2,000 feet in southern New England. White pine types intermingle with beech-birch-maple and aspen-birch, especially on sandy outwash material at lower elevations. Oak types occur on sunny, dry southern exposures within the northern hardwood region.

Characteristics of the important species in northern hardwood and the closely associated types that have a bearing on silvicultural treatment are outlined in table 1.

INSECTS AND DISEASES

Many insects and diseases cause damage to northern hardwood species. Only the most important are mentioned here—those the silviculturist ought to know about in evaluating the growth potential of individual trees.

Wood-decay fungi cause important losses in both volume and quality. The most important of these fungi are *Poria obliqua* (Per.) Bres. in birches, and *Polyporus glomeratus* Peck and *Fomes igniarius* (L.) Gill in maples and beech. In addition, several fungi cause discoloration, which makes the wood unsuitable for many quality products. Decay and discoloration fungi enter through wounds and dead branch stubs. The presence of large dead branch stubs on a tree strongly indicates that appreciable losses from decay and discoloration will be experienced.

The beech-bark disease is the most important lethal disease of beech. The beech scale *(Cryptococcus fagi* (Baer.)) punctures the bark, allowing a bark-killing fungus *(Nectria coccinea* var. *faginata)* to enter. Small vigorous trees sometimes survive the disease; large trees seldom survive.

Birch dieback has caused heavy mortality in both yellow and paper birch. The causes of this affliction have not been definitely determined. Although the disease has subsided, a recurrence is possible. A similar condition, commonly called post-logging decadence, often afflicts both paper and yellow birch after heavy partial cutting in northern hardwood stands.

In addition to the beech scale, one other insect deserves men-

tion: the sugar maple borer *(Glycobius speciosus* (Say)). The larval galleries made by this insect result in partial girdles and cankers that permit the entrance of discoloration and decay organisms, and increase susceptibility to wind breakage. The incidence of borer damage seems to be greatest in open or heavily thinned stands.

Management objectives in the northern hardwood region vary considerably. In developing an objective, the manager has to decide first whether he wants to aim toward a high proportion of top-grade products such as veneer logs, saw logs, and millwood, or concentrate on pulpwood and other bulk products.

A second basic decision—partly dependent upon the product objective—is whether to manage for a high proportion of tolerant species, intermediates, or intolerants.

Once a decision has been reached on product and species objectives, the manager must consider other timberland uses, as well as present stand and site conditions in arriving at a silvicultural prescription or long-term silvicultural program.

UNEVEN-AGED MANAGEMENT

Applicability

Uneven-aged management is implemented through selection cutting of individual trees or the harvesting of trees in small groups (two or three trees). Tolerant species (beech, sugar maple, hemlock, and spruce) are favored by this system. Intermediate species, primarily yellow birch, occur in small proportion, except where cutting has been unusually heavy. The system appears to be best adapted to producing sawlogs and veneer logs, with pulpwood as a byproduct.

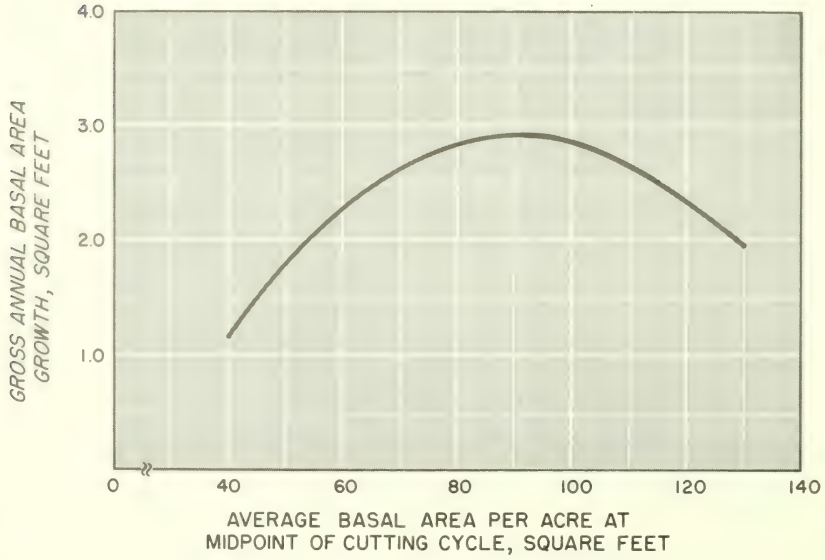
Aesthetically, many people prefer selection cutting because a residual stand always covers the site and disturbance from logging is less apparent. However, few intolerant trees are reproduced by selection cutting, and, unless the cutting is very heavy, so as

to result in an abundance of undergrowth, little browse may be produced for game animals.

Stocking, Structure, and Yields

Gross basal-area growth, as related to average basal area per acre, is illustrated in figure 2. Average basal area is the basal area at the midpoint of the cutting cycle. For example, a stand with a residual of 70 square feet that is expected to grow to about 90 square feet over the next decade would have an average basal area of about 80 square feet. This relationship applies to a fairly vigorous and well-balanced northern hardwood stand growing on an average site in the White Mountains of New Hampshire. Peak gross basal-area growth occurs between 80 and 100 square feet per acre in trees over 5.0 inches d.b.h. (diameter breast high). However, acceptable growth response occurs between 70 and 110 square feet per acre.

Figure 2.—Relationship of gross annual basal-area growth to average basal-area per acre for trees over 5.0 inches d.b.h. in uneven-aged northern hardwoods (average site).



For cutting cycles of 10 to 20 years, we recommend a residual basal area after cutting of 70 to 80 square feet. However, no cutting should remove more than about 40 square feet of basal area per acre.

Distribution of basal area and numbers of trees per acre for a typical stand at 80 square feet basal area is:

D.b.h. class (inches)	*Trees per acre (No.)*	*Basal area (square feet)*
6–10	60	20
12–16	30	28
18+	15	32
Total	105	80

In making a selection cutting, the manager should try to work toward this distribution of basal area among size groups. Numbers of trees in the 6- to 10-inch class often tend to be in excess of the recommended numbers, and it may not be commercially feasible to cut heavily in this size group.

Based on a gross annual growth rate of 2.75 square feet per acre for a stand with about 80 to 90 square feet average basal area, and an estimated 25 percent loss to mortality, the annual yield of a well-balanced stand is roughly 200 board feet of sawlogs and veneer logs plus 15 cubic feet of pulpwood. This total yield is equivalent to at least ½ cord annually. Since logging economics dictate a desirable cutting per acre of 6 to 10 cords, the appropriate cutting cycle would be 12 to 20 years.

Marking Guides

The success of uneven-aged management—both silviculturally and economically—depends to a large extent upon the choice and application of appropriate marking guides.

Marking guides are usually applied within limitations imposed by a minimum residual basal-area objective and, on the other hand, a minimum operable cut per acre. Once these limits have been defined, trees should be marked for cutting according to the following descending order of priority:

1. Salable trees, especially the valuable ones, that will not survive till the next harvest.

Table 2.—*Tree size objectives (d.b.h.) denoting peak of possible log-grade improvement (financial maturity) for northern hardwoods*

Species	Grade[1] potential	Predominant merchantable height	D.b.h. objective	Top d.i.b.
		Logs	*Inches*	*Inches*
Yellow birch	High	1	19	16
		2	22	16
	Medium	1	16	13
		2	18	12
Sugar and red maple	High	1	17	14
		2	20	14
	Medium	1	16	13
		2	18	12
Beech	High	1	16	13
		2	19	12
	Medium	1	15	12
		2	18	12
Paper birch	High	1	15	12
		2	15	8
	Medium	1	11	8
		2	12	6
White ash	High	1	15	12
		2	18	12
	Medium	1	15	12
		2	15	8

[1] High grade potential means that the first 1- or 2-log portion of the stem could produce grade 1 or veneer-grade logs. Medium grade potential means that the highest quality would be no more than grade 2. Grades are based on U.S.D.A. Forest Service standard specifications for hardwood factory lumber and veneer logs.

2. Salable trees that have reached the peak of merchantable volume growth, because of the progression of decay.

3. Trees of less desirable species; species that are not of primary interest within the current management objective.

4. Trees that have reached the peak of grade improvement. These trees are financially mature. Suggested tree-size objectives are given in table 2.

In addition, trees (such as wolf trees) that are affecting the growth of better individuals should be marked in preference to similar trees that are not greatly affecting other stems.

Timber Stand Improvement

Under individual tree selection and small group selection cutting, most of the necessary cultural work is provided for by the harvest cuttings when trees are marked down to about 8 inches d.b.h. However, during marking operations, cull trees should be marked for optional removal by the logging operator; or, as another alternative, the sale contract may require that the operator cut such trees—with an allowance on the stumpage for this work. After logging, any cull trees still remaining should be deadened, which can be done economically by applying a chemical.

Several chemicals and methods of application can be used effectively on the culls. For example, a mixture of 2,4,5-T ester and fuel oil can be applied with a tree injector in overlapping cuts made near the base of the tree. On trees up to 10 inches d.b.h., use a 40-pound aehg (acid equivalent per hundred gallons) dilution; on larger trees, use an 80-pound aehg dilution. Inject about 2 milliliters per cut. Normally, no timber-stand-improvement work in trees smaller than 6 to 8 inches d.b.h. will be justified, an exception being when a change in species composition is desired.

The time required to inject unwanted trees larger than 2 inches d.b.h. after a logging operation will range from 1 to 7 man-hours per acre. A fairly accurate estimate of treatment time, using an injector, can be made by applying the following equation:

$$Y = 1.31 + 0.0048\ X$$

where Y = man-hours per acre.
X = average size tree treated, multiplied by the number of trees treated per acre.

Regeneration

Selection cutting favors the tolerant species. Under light to moderate selection cutting, 80 percent or more of the regeneration (stocked-milacre basis) consists of beech and sugar maple, with some hemlock and spruce.

Conversion from Even-Aged to Uneven-Aged

Conversion from even-aged to uneven-aged management presents some special problems in marking and regeneration. Normally, a vigorous even-aged stand with a high proportion of intolerant-intermediate species should be maintained as an even-aged stand.

The general approach in converting a stand to the uneven-aged condition is to make a series of partial cuttings at 10- to 20-year intervals. Residual stocking should be between 70 and 80 square feet. The size distribution suggested on pages 6-7 should be gradually achieved.

These cuttings should gradually remove the shorter-lived species as they mature, as well as less desirable stems of the longer-lived species. Care should be taken to retain enough good stems (species and size) to maintain commercial cuttings at regular intervals. For example, you may want to retain some vigorous paper birch beyond maturity to ensure that commercial operations can be continued.

Regeneration sometimes is difficult during the conversion of a stand from even-aged to uneven-aged, especially on somewhat poorly drained or on excessively drained sites. Where weed species such as hobblebush and striped maple begin to fill in heavily, lighter cuttings (higher residual density) should be tried. On some areas, a heavy understory of beech may develop. Where the trend in regeneration appears to be unacceptable, reexamine the possibilities of even-aged management, using narrow strip cuttings (coupled with stump treatments) as described in the sections on even-aged management.

EVEN-AGED MANAGEMENT

Applicability

Even-aged management utilizes some form of clearcutting for the final cutting, and thus is particularly adapted to growing intermediate and intolerant species, commonly in association with tolerants. When used appropriately, even-aged management will produce high-grade sawlogs, veneer logs, and millwood. The

system also is well suited to pulpwood production, particularly in view of the trend toward greater mechanization in the woods.

A regular schedule of planned clearcuttings—properly distributed throughout the forest in both space and time—favors most large and small game, provided that softwood deer yards are reserved.

Aesthetically, even-aged harvesting is unsightly for a few years, primarily because of the unattractive heavy slash (which cannot be removed economically) and the remaining unmerchantable trees. This aesthetic problem can be minimized by maintaining roadside strips, or possibly by using narrow strip cuttings, which are less objectionable than large clearcuttings.

Regeneration Cuttings

Complete clearcutting consists of removing all merchantable trees on an area, followed by mechanical or chemical removal of all unmerchantable trees down to 2 inches d.b.h. When clearcutting is done from about May to August, an adequate seed source (adjacent stand, or seed trees) should be within about 4 tree heights of all portions of the clearcutting. Cutting during other months—when a fair to good seed crop is available—usually will result in adequate seed from the harvested trees.

Complete clearcutting will result in regeneration composed roughly of two-fifths intolerants, one-fifth intermediates, and two-fifths tolerants. The presence of beech or sugar maple advance regeneration indicates that these species will be well represented in the future stand. Heavy advance growth of tolerant species or weed species will have an adverse effect upon birch regeneration.

Clearcutting of immature stands frequently leads to a high proportion of weed species, especially **Rubus** spp. and pin cherry. However, evidence to date indicates that these weed species do not entirely prevent regeneration of the commercial species, although growth is retarded. If an immature stand contains a high proportion of red maple, vigorous sprout clumps will result. These should be removed. If aspen is abundant in the

clearcut stand, vigorous root suckering may result in an almost pure new stand of aspen.

Care should be taken to leave an uncut strip along main watercourses, and to place adequate water-bars on all skidroads to prevent soil washing. Skidroads should slope at 10 percent or less; they should not be laid out within 50 to 100 feet of temporary or main watercourses; and they should cross watercourses —if absolutely necessary—at a right angle.

Strip cutting consists of removing all merchantable trees in strips, followed by mechanical or chemical removal of trees down to 2 inches d.b.h. (fig. 3). We recommend removal in strips about 50 to 100 feet wide. These are usually laid out in an east-west direction, or—as a second choice—some direction that will facilitate harvesting. However, on poorly drained sites, it may be necessary to lay out the strips at right angles to the prevailing winds to help avoid windthrow—especially if the time interval between cuttings is too great to enable windthrow salvage.

First, every third strip is removed. Then 2 to 4 years later, one strip next to each initially cut strip is harvested; each second strip should be on the south or west side of the initial strip so that maximum protection against the hot sun is provided by the

Figure 3.—Strip cutting in an even-aged northern hardwood stand.

uncut strip. Then 2 to 4 years later, the final strips are removed. The final strip may be kept narrow, or seeded, or winter-logged, to facilitate regeneration.

Thus, the regeneration cutting extends over a 4- to 8-year period. Strip cutting appears to be more necessary for regenerating intermediate species (yellow birch and ash) than for regenerating intolerant species (paper birch especially). See **A Silvicultural Guide for Paper Birch in the Northeast.**[1] Furthermore, strip cutting may be more appropriate than large-scale clearcutting on excessively dry or wet areas, or where aesthetics are important.

If the harvested material is removed lengthwise down each strip, additional scarification probably will not be required. Usual precautions should be followed with regard to water-bars and limited cutting along main watercourses.

Patch cutting is the removal of all trees in areas of about 1/10 to ¾ acre in size. Silviculturally, patch cutting is desirable because it encourages regeneration of intermediate and intolerant species (the ratio depending upon patch size). However, because of difficulties in laying out, logging, and relocating patches, we generally recommend strip cutting, which equals patch cutting in silvicultural advantages and outweighs it in feasibility.

Shelterwood cutting has not been tested to any extent in northern hardwoods in the Northeast. No doubt shelterwood cutting of one form or another could be used to regenerate a mixture of tolerant and intermediate species, and—if the cuts were heavy enough—some intolerants as well. Specific recommendations on the use of shelterwood cutting must await further research.

Site Preparation Methods

Scarification prepares a favorable seedbed and thus promotes germination and establishment of paper and yellow birches. Where adequate scarification—about 50 percent of the area scari-

[1] Marquis, David A., Dale S. Solomon, and John C. Bjorkbom. A SILVICULTURAL GUIDE FOR PAPER BIRCH IN THE NORTHEAST. U.S.D.A. Forest Serv. Res. Paper NE-130, 47 pp., illus. NE Forest Exp. Sta., Upper Darby, Pa. 1969.

fied or disturbed—is not obtained as a byproduct of harvesting activity, or where the site is not naturally moist (for example, a large opening on a south slope), you should consider a special scarifying operation.

Scarification can be done with a track-type tractor and blade or rock rake (toothed blade). The objective should be to mix mineral soil and humus. Completely exposed mineral subsoil results in poor survival and growth. Scarification or disturbance of approximately 50 percent of an area requires about one to two D-6 tractor-hours per acre.

Removal of all unwanted stems (down to 2 inches d.b.h.) is required after clearcutting and strip cutting if the production of quality material is the objective. This can be done economically by applying a chemical. Several chemicals and methods of application can be used effectively. A mixture of 2,4,5-T ester and fuel oil can be applied with a tree injector in overlapping cuts made near the base of the tree. On trees up to 10 inches d.b.h., use a 40-pound aehg (acid equivalent per hundred gallons) dilution; on larger trees, use an 80-pound aehg dilution. Inject about 2 milliliters per cut.

The time required to chemically treat trees larger than 2 inches d.b.h. that are left after clearcutting and scarification will range from 1 to 5 man-hours per acre. A fairly accurate estimate of treatment time, assuming an injector is used, can be made by applying the following equation:

$$Y = 0.88 + 0.0041\ X$$

where Y = man-hours per acre.

X = average size tree treated, multiplied by the number of trees treated per acre.

After clearcutting, strip cutting, and so on, red maple stumps usually will sprout prolifically, especially from stumps smaller than 12 to 14 inches. Where potentially troublesome red maple stumps are abundant, we recommend treating them during the first or second growing season after cutting. Use a backpack spray apparatus to basal-spray all sprouts with a mixture of 2,4,5-T ester in fuel oil, making sure to drench the root collars. A 16-pound aehg dilution should be used.

If you treat only the vigorously sprouting stumps, it will require 1 to 2 man-hours per acre to stump-treat an average clearcut area.

Stocking Guides

Stocking guides for even-aged northern hardwoods (poletimber and larger)—based on numbers of trees, mean diameter, and basal area—are given in figure 4. These guides apply to the main crown canopy; they include intermediate to dominant trees that are in or touching the overstory. The B level represents minimum stocking for adequate growth. The C level represents the point where 10 years of growth will raise the stand to the B level. The A level represents an average unmanaged stand. Thus, stands above the A level are overstocked. Stands between the A and B levels are adequately stocked. Stands between the B and C levels are potentially adequately stocked. And stands below the C level are understocked.

Stocking guides for unmanaged, even-aged regeneration-sapling stands of northern hardwoods are given in table 3. Average numbers of acceptable stems required to produce at least B level stocking are given, together with high-confidence numbers—the numbers required to produce a well-spaced stand of acceptable stems, at least equivalent to B level stocking, with a high degree of confidence. Separate numbers of stems are given for all commercial hardwoods, and for intolerants-intermediates. We emphasize that the numbers in table 3 apply to acceptable stems of growing stock (considering species objectives, form, disease, and defect) in uncut stands.

Intermediate Cuttings

Cleaning or **thinning** is feasible under two situations: (1) when a noncommercial operation will increase net growth in volume and value sufficiently to make it a sound investment; and (2) when a commercial operation is possible.

Cleaning and thinning efforts should favor the selected crop trees, particularly by freeing the crowns on all sides. Normally this will require removal of one or two stems around each crop

Figure 4.—Stocking guides for even-aged northern hardwoods, based on number of trees in the main canopy, average diameter, and basal area per acre. Stands above the A line are overstocked. Stands between the A and B lines are adequately stocked. Stands between the B and C lines should be adequately stocked within 10 years. And stands below the C line are definitely understocked.

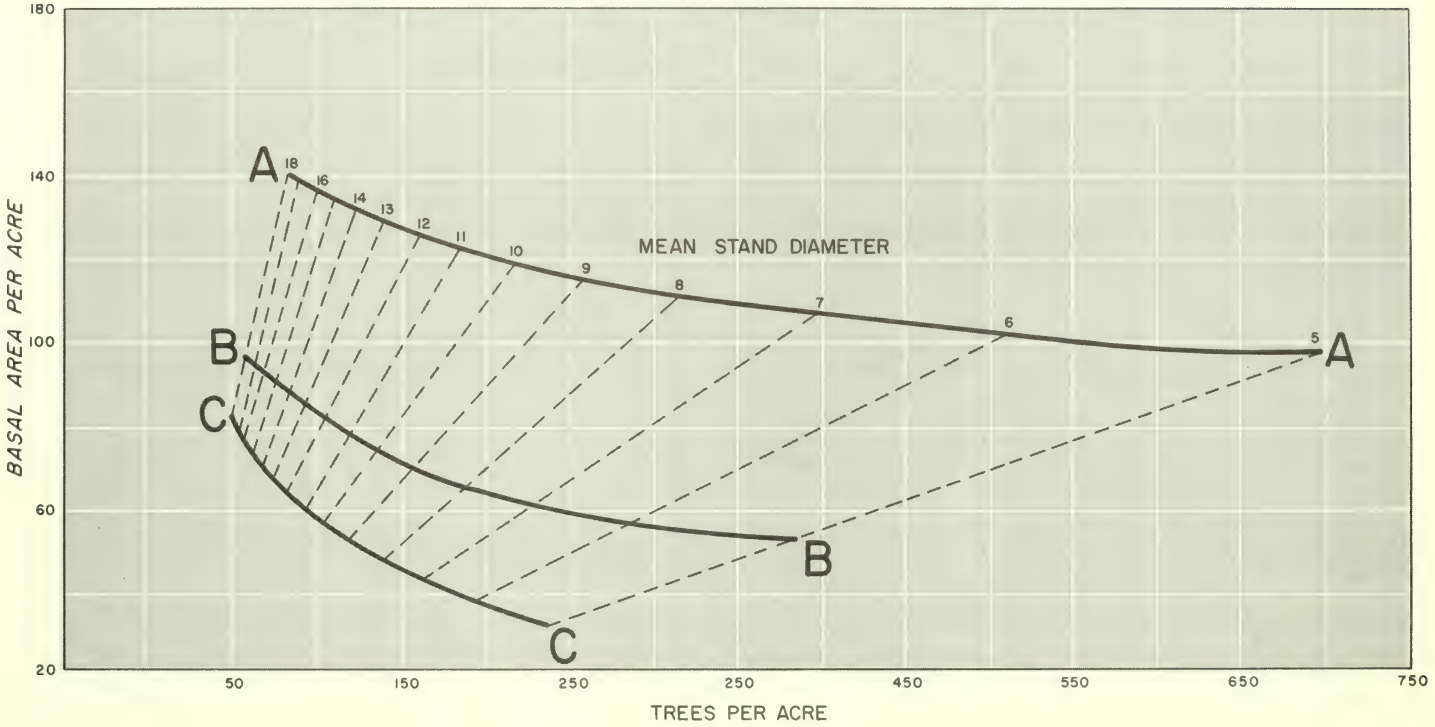


Table 3—*Number of acceptable stems of growing stock per acre, for given average stand diameters, required to meet at least B level stocking when the stand reaches 5.0 inches*[1]

Mean stand d.b.h. (inches)	Average	High-confidence
	No.	*No.*
ALL COMMERCIAL HARDWOODS		
1.0	2,050	3,480
2.0	1,390	2,320
3.0	890	1,550
4.0	580	770
INTOLERANTS-INTERMEDIATES		
1.0	1,430	2,320
2.0	1,040	1,930
3.0	730	1,160
4.0	540	770

[1] Based on stems 0.6 inch d.b.h. and over.

tree in the older stands, and one to four stems around each crop tree in the young stands.

The number and type of crop trees will depend upon the long-term silvicultural plan for the stand. If you plan to grow a crop of intolerant species, and then regenerate the stand, intolerant species should be selected as crop trees. See the recommendations given in **A Silvicultural Guide for Paper Birch in the Northeast.**[1]

In mixed stands, it is often reasonable to plan on an early medium-to-light harvest of intolerant species followed by a final harvest of intermediate or tolerant species. In such cases, you should select a number of intermediate and tolerant crop trees between the B line and A line to obtain the expected mean harvest diameter. In releasing such trees, paper birch should be retained—and released if no better crop tree is present—until they are merchantable and can form the basis for a commercial thinning. Growth of these paper birch would be improved indirectly by release of the longer-lived crop trees.

In all thinning, the B line would be used to set the minimum

residual stocking on the entire stand (all stems in the overstory or main age class).

We recomemnd treatment at about 10-year intervals, or as soon after 10 years as feasible. Cleaning or thinning should not begin before the stand reaches about 20 years.

In the field, thinning may be controlled by using practical guidelines on selecting crop trees and then releasing them. Acceptable crop trees are those of desirable species and good form and quality. More specifically, these crop trees should be:

- First priority: yellow birch, paper birch, sugar maple, and white ash. Second priority: other commercial species such as beech, red maple, oak, and hemlock.
- Dominant or codominant trees, and sometimes intermediate sugar maple or yellow birch.
- Trees that are free of sound or rotten defects such as rotten seams or holes, forks, severe crook in first log, damaged or defective crown, sapsucker injury, coarse branches, and so on.
- Trees that are reasonably windfirm—well anchored and without excessive lean. Avoid trees perched on stumps or large rocks.
- Seedlings or seedling sprouts. Avoid rootsuckers and stump sprouts if possible.

After the approximate number of crop trees to be released is decided upon, the spacing of crop trees can be determined by:

$$\text{Spacing} = \sqrt{43560 \,/\, \#\ \text{crop trees}}$$

Try to pick about one crop tree within each spacing distance, passing over areas that have no qualifying trees. The number of trees to remove per acre equals the number in the stand minus the number at the B line. The average number of competing trees to remove per crop tree would equal the number of competing trees per acre divided by the number of crop trees.

An example of the instructions to a field crew would be: "Pick about one crop tree every 7 paces, and remove **on the average** two competing trees per crop tree." By using instructions

of this nature, field crews can release the desired number of trees, well-spaced throughout the stand; and they can also achieve a desired residual basal area per acre with minimum supervision and training.

Pruning has seldom been tried on a commercial scale in northern hardwoods. However, the possibilities seem good. Sugar maple and yellow birch are the only species that warrant pruning, because of their value and relatively slow natural pruning. Pruning should be restricted to vigorous crop trees on good sites. The number of trees to prune should not exceed the B line at the expected harvest diameter.

Pruning about one full log on a 3- to 4-inch tree appears to be feasible and worthwhile. Ordinarily only a few branches need be removed. At least one-third of the tree should remain in green crown. If possible, trees with branches less than $1\frac{1}{2}$ to 2 inches in diameter should be pruned because wounds of this size heal most rapidly. We estimate that 10 to 20 trees could be pruned per man-hour.

Rotations and Yields

Final yields in cubic feet and board feet are given in table 4 for stands of given mean diameter. These yields apply to well-stocked mixed stands of northern hardwoods at site index 60 (b.h. age 50) for sugar maple. Approximate yields for a different site are given by multiplying each yield by S.I./60. Yields for stands that are understocked (as evidenced by basal area) or defective should be reduced accordingly.

Estimated numbers of years to reach a given mean diameter are given for a range of site indexes, and for unmanaged and managed conditions. Managed growth rates are considered attainable under current feasible levels of management intensity.

D.b.h. size objectives—by species, expected merchantable height, and grade potential—are given in table 2. The stand is at maturity when average diameter of the main overstory has reached, or is within 2 to 4 inches of, the appropriate size objective. For pulpwood production, trees over 16 inches d.b.h. frequently are uneconomical to handle. Thus, we recommend

Table 4.—*Yields per acre for a given mean stand diameter, and years to reach a given mean diameter by site index for both managed (thinned) and unmanaged stands of mixed northern hardwoods*

Mean d.b.h. (inches)	Volume per acre		Basal area	Site index					
				50		60		70	
				Managed	Unmanaged	Managed	Unmanaged	Managed	Unmanaged
	Bd. ft.	*Cu. ft.*	*Sq. ft.*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*
5.0	—	1,900	95	44	59	38	50	33	44
6.0	—	2,142	102	56	74	46	61	39	52
7.0	3,782	2,332	106	67	89	56	74	45	60
8.0	5,456	2,530	110	77	103	66	88	53	71
9.0	7,182	2,736	114	93	124	77	102	62	82
10.0	9,088	2,950	118	112	149	89	118	71	94
11.0	11,050	3,146	121	134	179	99	132	80	106
12.0	13,200	3,375	125	—	—	110	147	88	117
13.0	15,544	3,612	129	—	—	122	163	97	129
14.0	16,048	3,799	131	—	—	137	182	107	142
15.0	16,698	4,020	134	—	—	—	—	118	157

an average diameter of 10 to 12 inches where pulpwood production is the primary objective.

We have little data on long-term intermediate yields from managed (thinned) stands. However, from computer synthesis of available yield data, we believe that in addition to the final harvest yields given in table 4, an intensive thinning schedule will produce intermediate yields at least equal to the table 4 volumes. In other words, intermediate yields will about double the production.

DIAGNOSIS

Reproduction Stands and Sapling Stands

For our purposes, a reproduction stand is one that averages less than 1.5 inches d.b.h. A sapling stand is an even-aged stand between about 1.5 and 4.5 inches average diameter (fig. 5). We assume that even-aged management is planned for such stands, at least at the outset. Under present management intensities, reproduction and small sapling stands are seldom scheduled for silvicultural treatment. However, it is often desirable to assess the adequacy of stocking and species composition in such stands so that the success of past regeneration cuttings can be determined. Furthermore, timber stand improvement sometimes is required in such stands to maintain adequate stocking and species composition. Growth response is excellent at this young age; and pruning is most feasible during this period.

In diagnosing the stand, first estimate mean diameter of the trees over 0.5 inch for: (1) paper birch (and aspen, if commercially desirable), and (2) all commercial species. This can be based on a few plot measurements.

Then locate one plot center per acre up to a maximum of 50, and keep count of the number of plot centers.

Take one circular 6.0-foot-radius plot per location.

Classify each plot as **one or more** of the following:

Figure 5. — Even-aged sapling stand of northern hardwoods.

- **Unstocked**—no acceptable stems (stems that will produce better-than-pulpwood trees).

- **Stocked**[2]—has the following numbers of acceptable stems, or potential crop trees, of any commercial species:

Mean d.b.h. (inches)	*Stems per plot (No.)*
1.0	5+
2.0	4+
3.0	2+
4.0	1+

- **Stocked with paper birch**[2]—has the following number of good paper birch stems.

[2] If numbers of stems per acre are known, adequacy of stocking for any species or species group can be judged from table 3, which shows numbers required to meet B level stocking. Numbers required to meet C level stocking—minimum acceptable numbers—are approximately 50 to 60 percent of those shown in table 3.

Mean d.b.h. (inches)	*Stems per plot (No.)*
1.0	4+
2.0	3+
3.0	2+
4.0	1+

- **Minimum stocking**—has at least one acceptable stem per plot.

A suggested tally sheet for recording this information is given in the appendix; counts are converted to percentages by dividing by number of plots and multiplying by 100.

Estimate site index (base age 50) for: (1) paper birch and (2) yellow birch or sugar maple, whichever is predominant, by determining b.h. age and total height for at least 10 stems of each species. Determine site index for each stem from the curves in figure 6, and then average the results for each species. In reproduction stands, site measurements may not be feasible, in which case you will have to judge the site from either knowledge of the area or measurements in adjacent stands.

In mixed stands, it may be helpful to use the measured site index for one species to predict the site index of another. Figure 7 shows the relationship among site indexes (base age 50 years) for paper birch, yellow birch, sugar maple, and white ash. For example, if the measured site index of yellow birch is 60, then the comparable site index for paper birch will be about 65; for sugar maple 61; and for white ash 69.

Poletimber and Sawtimber Stands

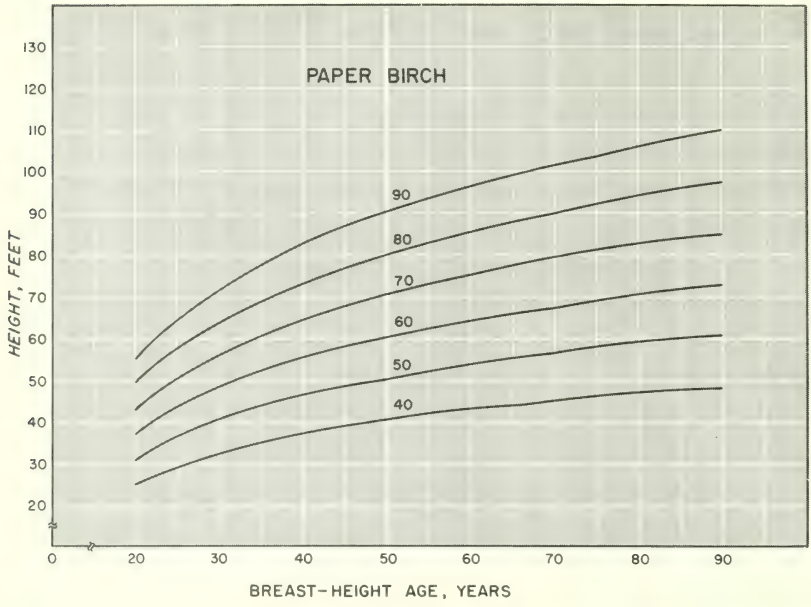
These are stands with average diameters of larger than 4.5 inches for the trees in the overstory or main crown canopy. They may be either even-aged or uneven-aged.

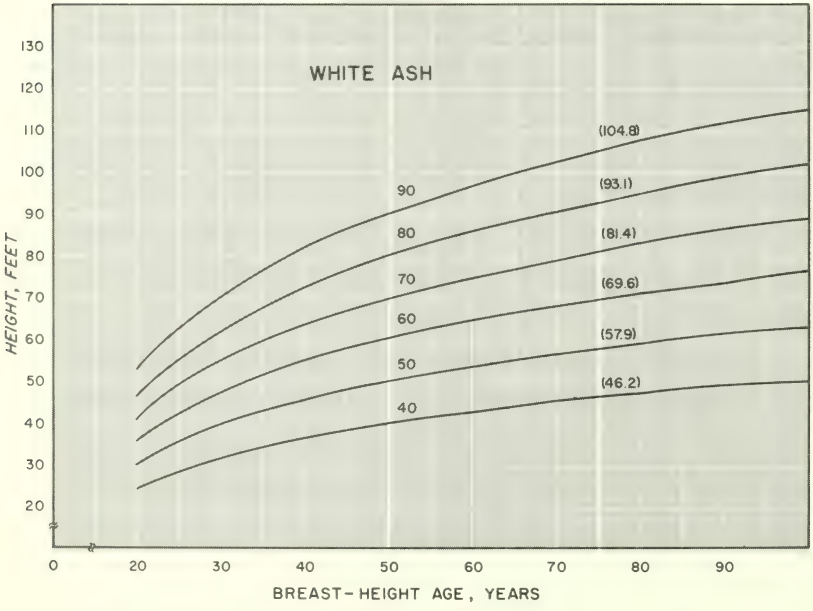
In diagnosing the stand, first classify it as even-aged (one main age class recognized) or uneven-aged (more than one distinct age class recognized).

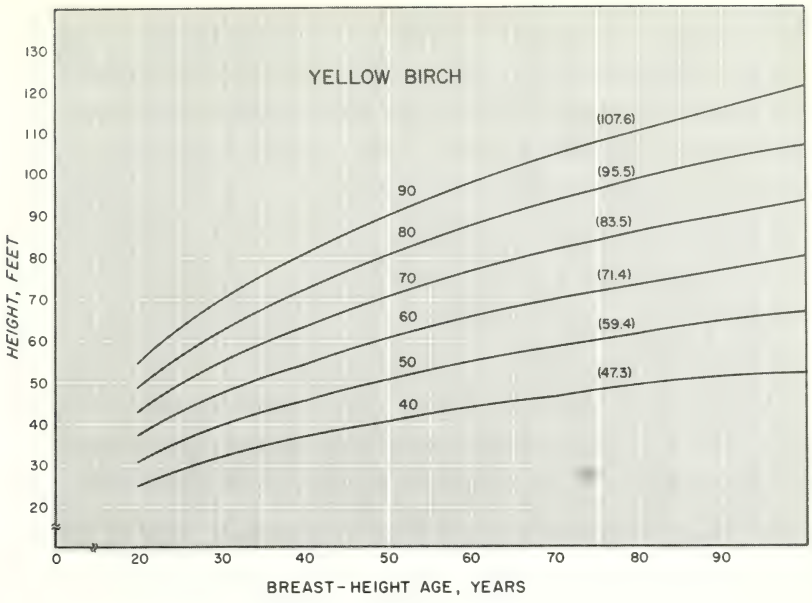
And you should decide next whether the objective for the area is uneven-aged management or even-aged.

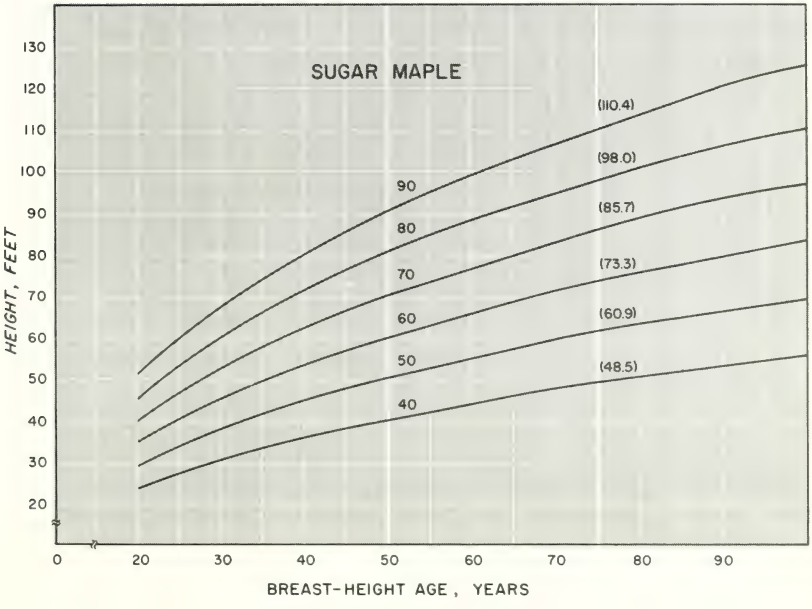
Take one systematically located sample point per acre up to a total of 50 points. With a 10-factor prism, record tree counts

Figure 6.—Site-index curves (breast height age 50) for paper birch, white ash, yellow birch, and sugar maple in Vermont and New Hampshire. Values in parentheses are for site index breast height age 75 for yellow birch, sugar maple, and white ash.






YELLOW BIRCH
HEIGHT, FEET
BREAST-HEIGHT AGE, YEARS
90
80
70
60
50
40
(107.6)
(95.5)
(83.5)
(71.4)
(59.4)
(47.3)


SUGAR MAPLE
HEIGHT, FEET
BREAST-HEIGHT AGE, YEARS
90
80
70
60
50
40
(110.4)
(98.0)
(85.7)
(73.3)
(60.9)
(48.5)

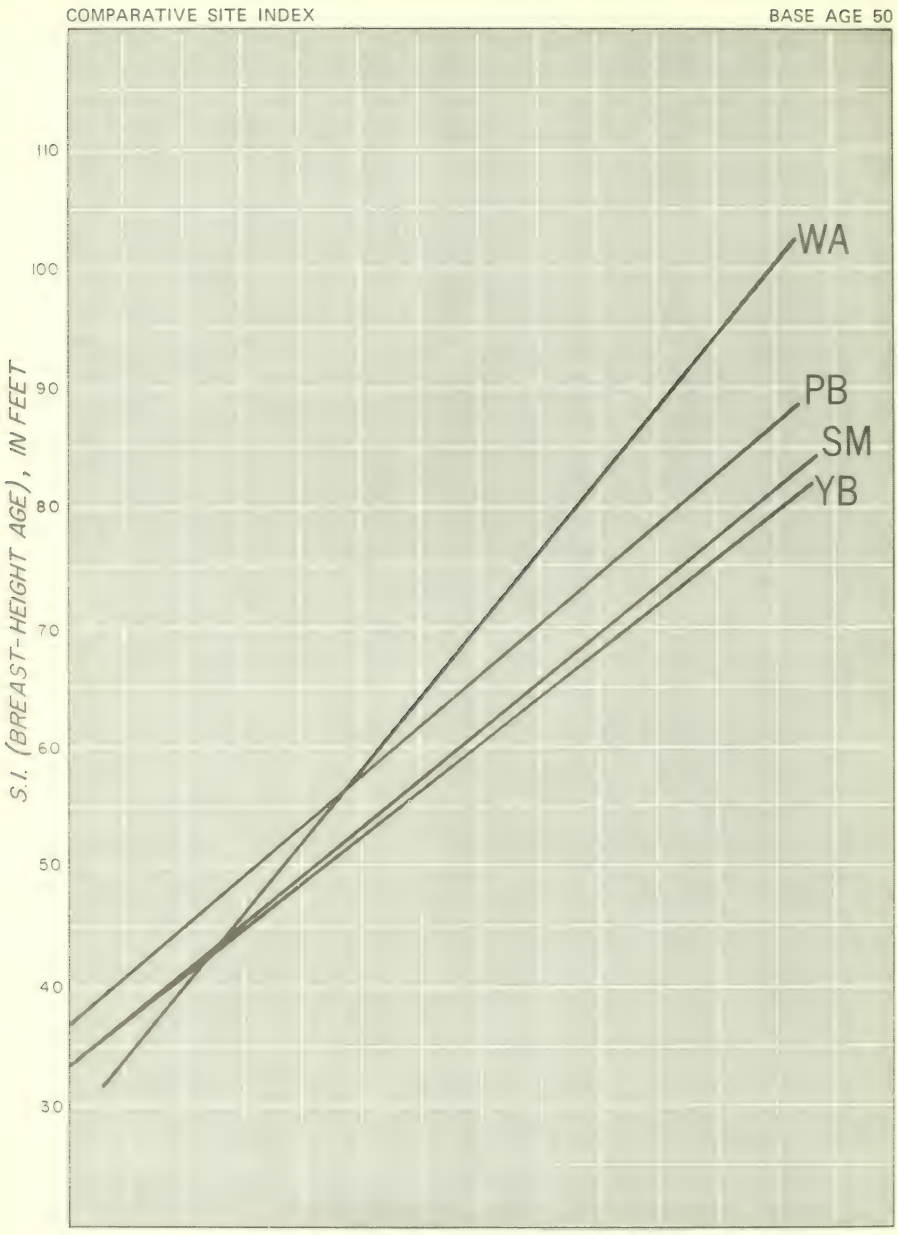


Figure 7.—Relationships among site indexes (base age 50) for four northern hardwoods. To estimate site index of species X from site index of species Y: find known site index on curve for species Y; move vertically up or down to curve until you locate species X; read horizontally across to the left to find estimated site index for species X.

in the classes indicated below, and summarize for the area as follows:

Class	*No. trees per acre*	*Basal area**	*Mean d.b.h.**
Paper birch acceptable stems	—	—	—
Other acceptable stems	—	—	—
Undesirable stems	—	—	—
Total	—	—	—

* Basal area is the average count times prism factor, and the mean d.b.h. is found by dividing basal area by number of trees per acre and, using table 5, converting from basal area back to mean d.b.h. Or, you can use figure 6 to estimate mean d.b.h. from basal area and number of trees. A convenient tally sheet for recording this information is given in the appendix. (In uneven-aged stands, mean diameter need not be calculated.) See table 5 for basal area-d.b.h. conversions.

Undesirable stems are those that will not make saw log or veneer log material now or in the future (but may qualify as pulp).

Table 5.—*D.b.h.-basal area table*

D.b.h.	Basal area per tree	D.b.h.	Basal area per tree
Inches	*Square feet*	*Inches*	*Square feet*
1.0	0.0055	11.5	0.7213
1.5	.0123	12.0	.7854
2.0	.0218	12.5	.8522
2.5	.0341	13.0	.9218
3.0	.0491	13.5	.9940
3.5	.0668	14.0	1.0690
4.0	.0873	14.5	1.1467
4.5	.1104	15.0	1.2272
5.0	.1364	15.5	1.3104
5.5	.1650	16.0	1.3963
6.0	.1963	16.5	1.4849
6.5	.2304	17.0	1.5763
7.0	.2673	17.5	1.6703
7.5	.3068	18.0	1.7671
8.0	.3491	18.5	1.8667
8.5	.3941	19.0	1.9689
9.0	.4418	19.5	2.0739
9.5	.4922	20.0	2.1817
10.0	.5454	20.5	2.2921
10.5	.6013	21.0	2.4053
11.0	.6600	21.5	2.5212

In even-aged stands, the count should include only those trees with crowns in or touching the main overstory—only those intermediate to dominant trees that comprise the main portion of the stand.

In even-aged stands, determine b.h. age and total height for 10 stems or more of (1) paper birch and (2) yellow birch or sugar maple (whichever is predominant).

Judge whether a commercial cutting is now feasible, based on volume, quality, accessibility, markets, and so on. Note whether this cutting would be restricted to either a partial cutting or a clearcutting.

CHOICE OF PRESCRIPTION

The Key

Use the following key to identify the condition and find the appropriate prescription for treatment of that condition. The key to the prescription is the letter (A, B, C, etc.) at the right. Details of the prescriptions are presented in the next section.

Condition	Prescription
I	
REPRODUCTION OR SAPLING STANDS	
(mean d.b.h. up to 4.5 inches)	
1. 50 percent or more of the plots (6.0-foot-radius) stocked with paper birch; or management for paper birch primarily is desired	A
1. Less than 50 percent of the plots (6.0-foot-radius) stocked with paper birch; or management for paper birch is not desired.	
2. 50 percent or more stocked (all commercial species).	
3. Yellow birch-sugar maple site index $>$ 55	B
3. Yellow birch-sugar maple site index $<$ 55	C
2. Less than 50 percent stocked (all commercial species).	
3. 50 percent or more of the plots have minimum stocking.	
4. Yellow birch-sugar maple site index $>$ 55	D
4. Yellow birch-sugar maple site index $<$ 55	E

Condition	Prescription
3. Less than 50 percent of the plots have minimum stocking	F

Condition	Prescription

II
POLE OR SAWTIMBER STANDS

(mean d.b.h. of overstory more than 4.5 inches)

1. Stand condition uneven-aged (more than one primary age class).	
2. Objective: uneven-aged management (tolerant species).	
3. Basal area per acre of acceptable stems (better-than-pulpwood potential) less than 40 square feet	G
3. Basal area per acre of acceptable stems 40 square feet or more.	
4. Total basal area per acre 100 square feet or more.	
5. Commercial cut feasible	H
5. Commercial cut not feasible	I
4. Total basal area per acre less than 100 square feet	I
2. Objective: even-aged management.	
3. Clearcutting commercially feasible.	
4. Objective: intermediate species, especially yellow birch, in mixture with tolerants and some intolerants	J
4. Objective: intolerant species, especially paper birch, in mixture with tolerants and intermediates	K
3. Clearcutting not feasible	L
1. Stand condition even-aged (one main age class).	
2. Objective: uneven-aged management, tolerant species	M
2. Objective: even-aged management.	
3. Stocking of paper birch 50 percent of B line (poletimber stands) or 50 percent of total basal area (sawtimber stands); or management for paper birch primarily desired	N
3. Stocking of paper birch less than 50 percent of B line (poletimber) or 50 percent of total basal area (sawtimber); or management for paper birch primarily not desired.	

4. Stocking of acceptable stems (better-than-pulpwood potential) other than paper birch less than C line ..... O
4. Stocking of acceptable stems other than paper birch above C line.
5. Stand mature.
6. Objective: intermediate species, especially yellow birch, in mixture with tolerants and some intolerants ..... J
6. Objective: intolerant species, especially paper birch, in mixture with tolerants and intermediates ..... K
5. Stand not mature.
6. Total stocking less than halfway between A and B lines ..... P
6. Total stocking halfway between A and B lines or more.
7. Commercial thinning feasible now or within 10 years ..... Q
7. Commercial thinning not feasible now or within 10 years.
8. Site index of yellow birch-sugar maple > 55 ..... R
8. Site index of yellow birch-sugar maple < 55 ..... S

Prescriptions

These prescriptions are aimed toward production of saw logs, veneer logs, and millwood. Only commercial operations are recommended for pulpwood.

A. Use the prescriptions in *A Silvicultural Guide for Paper Birch in the Northeast*. If 50 percent or more stocked with paper birch, the stand should develop naturally into a poletimber stand with at least C level paper birch stocking.

B. This young stand probably will develop into an adequately stocked poletimber stand. Timber stand improvement (cleaning) is not urgent;

but for added growth, it would be desirable in a sapling stand. If cleaning is done, consider pruning a number of yellow birch and sugar maple crop trees equal to or less than B line at expected harvest diameter.

C. This young stand probably will produce an adequately stocked poletimber stand. Timber stand improvement (cleaning) is not urgent, and probably is not justified because of low site quality.

D. This young stand probably will not develop naturally into an adequately stocked poletimber stand. Since site quality is reasonably good, timber stand improvement (cleaning) is required and justified to produce an adequately stocked poletimber stand. Release crop trees (other than paper birch) at least equal in number to those at B line for expected harvest diameter. In addition, release up to 100 paper birch crop trees per acre, if available, for an early commercial cutting. In sapling stands, consider pruning a number of yellow birch and sugar maple crop trees equal to or less than B line at expected harvest diameter.

E. This young stand probably will not develop naturally into an adequately stocked poletimber stand. Since the site is fairly poor, timber stand improvement is not high priority. Plan on allowing the stand to develop until an early clearcutting operation is commercially feasible.

F. Stocking of this young stand is too poor to produce an adequate stand. No timber stand improvement is warranted. Plan on a clearcutting as soon as commercially feasible.

G. This stand is poorly stocked with quality stems. Reconsider the possibilities of clearcutting, in one form or another, and starting even-aged management.

H. Apply selection or small-group selection cutting, leaving about 70 to 80 square feet of basal area per acre in trees 6 inches d.b.h. and over.

I. Normally, no treatment should be considered for the next 10-year-period. However, if the stand consists of larger culls overtopping better younger growing stock, remove the culls chemically or by girdling.

J. Apply a progressive strip cutting, or a clearcutting with reserved yellow birch seed trees (1 to 2 trees per acre).

K. Apply a clearcutting, using reserved paper birch seed trees if logging is done between early May to mid-August.

L. Wait 10 to 20 years if merchantability is improving, then reconsider for strip cutting or clearcutting. However, if the stand is overmature and defective — if merchantability will not improve — remove the stand in strips or completely by cutting, girdling, or chemical means.

M. Apply partial cutting at 10- to 20-year intervals to remove shorter-lived species as they mature. As conversion to tolerant species pro-

gresses, follow recommended marking guides and stocking levels for uneven-aged management.

N. See *A Silvicultural Guide for Paper Birch in the Northeast.*

O. Stocking of species other than paper birch is inadequate. Plan to harvest paper birch when it reaches merchantable size; clearcut or strip cut remainder of stand at the same time, or later as soon as commercially feasible.

P. Do nothing now; reexamine in 10 years.

Q. Apply a commercial thinning now or within 10 years, reducing stocking to the B level (plus an allowance of perhaps 10 square feet for logging damage).

R. Because of reasonably good site and stocking, this stand warrants precommercial thinning. Reduce stand to B line (no logging damage allowance). Favor intermediate and tolerant crop trees equal in number to those between B and A lines for expected mean harvest diameter. Retain paper birch for early commercial harvest.

S. Do nothing now; wait until commercial thinning is feasible.

■

TALLY SHEET FOR REPRODUCTION OR SAPLING STANDS

Class	Count[1/]	Percent
Unstocked		
Stocked		
Stocked with paper birch:		
Minimum stocking		
Number of plots:		
Site index trees:		
Age		
Height		
Site index		

Stand type: ☐ Reproduction

☐ Sapling

[1/] One plot may be counted in more than one class.

Figure 8.—A suggested dot-count tally sheet for reproduction or sapling stands.

TALLY SHEET FOR POLETIMBER AND LARGER STANDS

D.b.h. Inches	Conversion,[1] trees per acre	Paper birch			Other acceptable stems			Undesirable		
		Tree count	Average count[2]	Trees per acre	Tree count	Average count	Trees per acre	Tree count	Average count	Trees per acre
2	458									
4	115									
6	51									
8	29									
10	18									
12	12.7									
14	9.4									
16	7.2									
18	5.7									
20	4.6									
etc.	etc.									
Total										

Stand class: ☐ Even-aged
☐ Uneven-aged

Commercial cutting: ☐ Feasible
☐ Not feasible

Number of points:

Site index trees:
Age
Height
Site index

[1] The number of trees conversion (10 factor) provides the number of trees per acre by multiplying the conversion times the average count.

[2] Average count = total count for each diameter class/number of points.

Figure 9.—A suggested tally sheet for poletimber and larger stands.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The Silviculture of Oaks and Associated Species

a summary of current information
presented at the Society of American
Foresters annual meeting at
Philadelphia, Pa., October 1968

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

FOREWORD

OAKS AND THEIR ASSOCIATED species occupy 48 percent of the commercial forest area east of the Great Plains—more than a third of the total commercial forest land in the United States. These species range from southern New England west to the Great Lakes and beyond, and south to the Gulf of Mexico, supplying most of the hardwood volume used by the Nation's forest-products industries.

Expanding demand for these species throughout their wide range has led to rapidly increasing interest in their management, together with the realization that the knowledge required for such management has been slow to accumulate. In response to this interest, a symposium was presented by the Division of Silviculture of the Society of American Foresters at their annual meeting in Philadelphia, Pa., in October 1968, to summarize present knowledge about the silviculture of the upland oak types and some associated hardwood species. The papers given at this symposium present up-to-date research findings in the fields of natural and artificial regeneration, stand density and growth, site quality determination, and tree improvement.

The importance of the material covered and the demand for copies of the papers made it desirable to provide wider dissemination of this information. I am pleased that the Northeastern Forest Experiment Station was able to play a significant role in both the formulation and publication of this work for the forestry profession.

—R. D. LANE
Director,
Northeastern Forest Experiment Station
Forest Service, U. S. Dep. Agriculture

The Silviculture of Oaks and Associated Species

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MEASURES NECESSARY FOR NATURAL REGENERATION OF OAKS, YELLOW-POPLAR, SWEETGUM, AND BLACK WALNUT

by F. BRYAN CLARK, *assistant director, Timber Management Division, North Central Forest Experiment Station, Forest Service, U. S. Department of Agriculture, St. Paul, Minnesota, maintained in cooperation with the University of Minnesota.*

WE KNOW A LOT about the basic requirements for seed germination and for seedling growth and development of various hardwoods. But to date we have been able to do little to create specific conditions to favor one hardwood species over another. Often good stands follow harvest cuts, but we can take little credit for composition except for yellow-poplar. If we are going to have a real influence on species composition we must be prepared to incur added expense. On most upland oak sites we will have to continue to use extensive means to influence composition. However, such extensive methods as maintaining proper stocking as stands approach maturity appear to do a satisfactory job in relation to the values involved.

The task of the forest manager before harvest time is to find the most economical way to provide environmental conditions that not only favor desired reproduction but also maintain good growth and quality in the maturing stand. To do this, he must know site quality and the silvical requirements of both wanted and unwanted species common to the area.

One of the guiding principles of silvicultural treatments for oaks, yellow-poplar, sweetgum, and black walnut is that these species are intolerant or intermediate in shade tolerance. The stand in which these species grow, whether it covers ¼ acre or 40 acres, must be even-aged.

GENERAL INFORMATION

Little is known about ways to stimulate hardwood seed production. The forest manager must continue to rely on proper stand density and selection to increase seed production. He must develop large-crowned, vigorous trees in the right location to regenerate stands on specific sites. For oaks this means that the desired seed source must be encouraged on the site to be regenerated. Though rodents and birds account for much oak seed dissemination, the seeding range of oak must be considered to be under and adjacent to the seed-tree crowns.

Yellow-poplar is another story. Past research has shown that seedfall patterns are predictable (*6, 11*). We know that most of the seed falls within 300 feet of seed trees. We also know that the seed will be dispersed north and east of a seed tree by the prevailing winds. Thus yellow-poplar reproduction cuttings must be concentrated north, east, and beneath the seed source.

The seedfall characteristics for sweetgum are similar to those of yellow-poplar, and the seeding range is about 200 to 300 feet (*13,15*). Many hardwood direct-seeding trials have failed because rodents and birds pilfered the seed, yet practically all natural walnut seedlings and much oak reproduction originates from rodent-buried seed. For oak and walnut, significant numbers of seedlings are established only during bumper seed years.

The potential for advance reproduction to produce the new stand is receiving more attention. Research now under way promises to yield more definitive information to replace some of the art in silviculture with physiological principles. Yet standards for determining the adequacy of advance reproduction are lacking. Four hundred good stems per acre of desirable species were judged to be sufficient advance understory for making a harvest cut in a poorly stocked stand of upland central hardwoods (*33*). In contrast, for West Virginia oak types, 4,000 advance seedlings per acre were recommended as the minimum to reproduce a new oak stand (*7*). In practice, the type of advance reproduction, whether seedling or seedling sprout, plus species, size, vigor, and distribution, are important considerations—along with total numbers and competition from unwanted trees and shrubs.

Better fire protection, reduced grazing, and lack of fuelwood cutting are proposed by various authors as reasons for increased amounts of unwanted tolerant species in the understories on better hardwood sites. A comparison of burned and unburned areas in Rhode Island showed that fire favored the "intolerant sprouters," white, scarlet, and black oaks (2). The role of fire in favoring certain oak species over other trees relates to the sprouting ability of the oaks. Though many species sprout after the tops are killed by fire, it is vigor and sprouting consistency that give oak the ecological advantage.

Harvest cutting method can influence species composition. However, species vary in their response to how the overstory is removed. In Ohio, cutting intensity had no influence on the total number of oak stems; but after 10 years, clearcut plots had the most oaks in the dominant canopy of the new stand (*26*). For yellow-poplar the story was different: clearcutting with attendant large amount of scarification produced as much as 10 times more seedlings as selection cutting. Most yellow-poplar seedlings established after light cuts die from lack of light and/or moisture. So a number of environmental factors influence the establishment of trees in the new stands. Fortunately, most of these factors can be altered.

OAKS

Oaks are reproduced before the harvest cut, not after. Research in various localities showed that the amount of oak in the new stand depends directly upon advance reproduction[1] (*1,7,22*). The ability of seedlings to become established for a year or two is not the critical factor in regenerating oaks. Flushes of new seedlings in good seed years are characteristic, but most of these seedlings die during the first year or two. It is the ability of some of these seedlings to become well established and grow before the overstory is removed that permits oaks to compete in the new stand.

The build-up of advance oak regeneration on a specific site was found to be related to the particular set of environmental

[1]Sander, Ivan L., and F. Bryan Clark. *Reproduction of upland hardwood forests in the Central States.* In Press, U. S. Dep. Agr. Handbook.

conditions that exist on the site (*7, 8*). In these studies percent of sunlight on the forest floor and aspect were correlated with the amount of advance reproduction. The authors reasoned that on south and west exposures the more open stands permit more sunlight to reach the forest floor and favor oak establishment. They also found that partially cut, lightly burned, or grazed stands had the most advance reproduction.

Amount of established oak reproduction varies greatly. In West Virginia a range of 125 to more than 55,000 oak seedlings per acre was reported (*32*). Moreover, nearly half of the areas studied had at least 3,000 oak seedlings per acre. In other studies the numbers of advance oak seedlings ranged from thousands per acre in Ohio to only 230 per acre in mixed hardwood plots in Indiana.[1]. And plots in southern Illinois had an average stocking of 500 advance and 650 new oak seedlings 4 years after cutting in oak-hickory and mixed hardwood stands.

New sprouts from advance reproduction are the most desirable form of oak reproduction (*26*). Such sprouts develop after established trees are injured during logging or after sudden overstory removal. Six years after cutting in Illinois, new sprouts were 14 feet tall, trees from advance reproduction that did not sprout were 6 feet tall, and new seedlings were only 1 foot tall.[1] Thus the amount, size, and origin of advance oak reproduction strongly influence the composition of the new stand. It is well established that, through fire and other factors causing top dieback, the roots of advance oak reproduction are usually several years older than the tops. It is probably the "imbalance" between top and root size and condition that causes many shrubby, flat-topped oak seedlings to send up a new, vigorous sprout when suddenly released from the overstory. If it were not for this mechanism and logging injury, much advance oak reproduction would compete poorly with other species.

Advance oak reproduction is more abundant on medium and poor sites than on good sites (*23,34*). In New Jersey, oak was easier to establish on well-drained drier sites than on poorly drained sites (*30*). The poorly drained sites had an advance understory of shrubs and herbs that responded quickly to cutting and crowded out oak seedlings. Though such sites produce good hardwood timber, the possibility of economically

producing oak stands without special treatment is slim. The lack of aggressiveness in seedling oaks precludes getting enough new reproduction through the rank growth of weeds and shrubs. Though the use of herbicides before harvest holds some promise, the expense of repeat applications for several years cannot be justified for oak. Consequently, we may have to accept mixed hardwoods on good sites and manage for oak where it can be more easily maintained in the dominant stand.

Bottomland species such as pin oak and willow oak are different. Wet-site oaks tolerate flooding that other species cannot survive. However, the weed and shrub problem is acute. As with the upland oaks, advance reproduction is the key to establishing the new stand.

Pin oaks, for example, reproduce in waves, thousands of seedlings per acre following heavy seed crops. The usual dense overstory canopy suppresses the seedlings and they die in dry summer months. Under management, drastic treatments will be necessary to reproduce the common even-aged pin oak stands. The present pure stands are the result of drastic treatment, usually clearcutting and even clearing. Detailed procedures have not been perfected for reproducing pin oak, but research in progress provides guidelines (*24*). Because of the different moisture regimes in uplands and bottomlands, it will not be possible to keep the overstory density in bottomlands as low as on uplands to encourage the establishment of advance reproduction. Keeping the stands too open for a period of 10 to 20 years will encourage the development of a jungle of shrubs and vines. The approach must be to capitalize on the frequent, large seed crops by timing the final cut several years after a bumper crop of seedlings has been established.

Specific data on the influence of light intensity for oak germination and establishment are scarce. Judging from the abundance of seedlings of various oak species that become established under fairly dense stands, high light intensity obviously is not required for germination and early establishment. However, for growth the different oak species probably differ in light requirements. White oak persists as an understory tree much longer than other oaks, but this persistence probably relates to drought tolerance as well as low-light-intensity tolerance. White oak is reportedly more efficient in

producing seedlings than red oak (*32*). Recently it was shown that full sunlight produces the most vigorous red oak seedlings (*21*).

The usual 1 or 2 inches of litter had little influence on the number of oak seedlings established through natural seedfall in upland sites (*23*). But in a study of bottomland reproduction, heavy litter restricted hardwood reproduction, including pin oak (*16*). Disking to provide a better seedbed increased the number of new red oaks in Wisconsin (*27*) and pin oaks in Missouri (*24*). However, disking was judged to be economically impractical in both cases. Disking after a bumper seed crop in Indiana greatly increased the number of white oak seedlings. Here again, the number of new seedlings on the undisturbed litter was adequate. With normal litter accumulations there should be no need for disking to increase oak regeneration.

Invasion of mixed oak stands by sugar maple, American elm, American basswood, and other hardwoods has created problems in oak regeneration cuts in Wisconsin (*28*) and elsewhere to the east. These mesic species are evidently invading areas where they had been excluded by wildfire. Lack of advance oak reproduction in southern Wisconsin has caused much concern to forest managers. The stands are about 100 years old and date back to the time when the widespread Indian practice of burning ceased (*10*). Oak brush or "grubs" had survived annual burning, and when the fires stopped, these trees developed into stands that probably represent a fire subclimax. Stand treatment and/or density have prevented the establishment of advance reproduction that can compete successfully with the other trees, shrubs, and weeds when the overstory is removed. Obviously we must find a more efficient way to establish oak reproduction other than by repeated wildfires. We need to know when and how to thin stands to permit the establishment, growth, and development of advance reproduction. Getting new seedlings is only a small part of the problem. New seedlings must be nurtured to the point where they are vigorous enough to compete with other plants when released by harvest cutting.

Why is reproduction lacking in places like Wisconsin, Minnesota, Iowa, and possibly Missouri while seemingly the problem is not so prevalent in states to the east? Fire may be the answer. Forests in the western edge of the oak range are the

result of annual Indian-, settler- and farmer-caused fires. Now the fire-born stands have come of age and enough time has not passed or the treatment has not been right for the development of an oak understory. If time since fire cessation is an important difference between eastern and western oak stands, then the forest manager is in for a difficult job in reproducing oak where well-developed advance reproduction is absent. Site quality and stand age are undoubtedly contributing factors. By multiplying the probabilities of (1) an oak seed crop, (2) a season favorable for germination, and (3) conditions favorable for understory seedling growth, it is easy to see that, left to chance, it will take many years to reproduce oak stands where advance reproduction is lacking.

Advance reproduction must be capable of responding vigorously to release after harvest cutting in order to stay dominant. Recently, the response of individual oak seedlings to a heavy, single-tree selection cut was studied in detail (*5*). This study showed that for red and white oak seedlings, crown conformation (whether the seedling is flat-topped or single-stemmed) was the key factor in predicting seedling vigor following release. Variation in sunlight from 6 to 90 percent failed to yield a significant growth correlation. It was concluded that either the shade-tolerant seedlings received adequate light or that the root systems did not completely adjust to the new growing conditions during the 4-year study period. Careful study of individual trees showed that non-erect seedlings tend to straighten; flat-topped seedlings respond gradually and some establish active leaders; and a few flat-topped seedlings produce a basal sprout after release.

Clearcutting a southern Michigan oak stand after a good acorn crop failed to produce a new stand with oak as an important component (*14*). Oak seedlings were established but did not grow fast enough on this good site to compete with more vigorous species. The few oaks established in the new stand are sprouts. This case is not isolated; experimental cuttings on good sites in Indiana gave the same results. In the Michigan studies the authors suggested that early cleanings must follow harvest cuttings on good sites. This prescription might keep advance reproduction in the new stand but probably not newly established seedlings. Mistblowing was unsuccessful in

controlling brush to release oak in Wisconsin because of regrowth and lack of herbicide selectivity.[2]

Arend and Scholz[2] recommend a two-cut shelterwood system where oak advance reproduction is lacking. They cite examples where three-cut shelterwoods in Wisconsin resulted in about 3,000 seedlings per acre. They also suggest the possibility of disking and mowing to control brush and encourage oak sprouts.

Because of the prevalence of advance oak reproduction in West Virginia, the one-cut shelterwood method has been suggested for regenerating areas ready for harvest (*32*). A good review of evidence favoring the shelterwood method for oaks is made by Smith (*29*). More recent research corroborates this general observation on the desirability of this method for upland oaks.

The only real difference between this type of shelterwood and one of the common present practices is the current usage of the term *clearcutting*. Smith suggests the use of the term *shelterwood* is best from the silvicultural standpoint if advance reproduction is involved. The so-called one-cut shelterwood differs from clearcutting in one important aspect: shelterwood presupposes adequate reproduction of desirable species before the final cut. If the shelterwood concept is carefully followed, the forest practitioner will avoid one of the pitfalls of even-aged oak management. While lack of advance reproduction does not seem to be a problem on most upland sites in the East, experience in the western edge of the oak range indicates that the inadequacy of advance reproduction must not be overlooked.

The sudden removal of an overstory not previously thinned or partially cut generally results in an even-aged stand originating from tolerant advance reproduction and intolerant new seedlings of such species as yellow-poplar. If the site quality is high enough, this might be the best treatment for obtaining the new stand. If the site is best suited for oak, then the more classical shelterwood approach is probably best. Here the objective is to grow an even-aged stand during the first 30 to 40

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[2]Arend, John L., and Harold F. Scholz. *Oak forests of the Lake States and their management.* U. S. D. A. Forest Serv. Res. Pap. NC-31, 36 pp. N. Cen. Forest Exp. Sta., 1969.

years dense enough to produce quality stems. Then by favoring species and quality, stand density is reduced to about 60 square feet of basal area per acre to permit continued crown development on trees selected for maximum growth and seed production. After this cut there is enough light and moisture to permit oak establishment but not enough to encourage the rapid development of intolerants. A cut that is too heavy at this point may encourage unwanted trees and shrubs. One or two more thinnings upgrades the residual stand quality and provides more overstory growing space. At the same time more oak becomes established and seedlings grow into the sapling stage. Finally, the overstory is removed and the well-developed understory is released to grow into an essentially even-aged stand.

Caution must be practiced in using the shelterwood method to encourage oaks. In a harvest-methods study in southern Indiana uplands, a preparatory shelterwood cut removed about half of the board foot volume. New oak seedlings became established before the final cut, but these new seedlings could not compete with the advance growth stimulated by the heavy cut. Five years after cutting, dominant- and codominant-tree heights in the shelterwood and clearcut plots were as follows:

	Shelterwood (feet)	*Complete clearcut (feet)*
Red oaks	2.0	8.5
White oaks	4.8	11.0
Yellow-poplar	6.6	12.0
Sugar maple	4.5	14.2

The trees left in the shelterwood suppressed growth but did not increase the number of oaks in the dominant stand. Removing the shelterwood residual overstory caused much damage to understory trees.

So the balance between not enough light and moisture and too much is delicate when attempting to establish advance oak reproduction. Long intervals between cuts or repeated light cuts may also encourage the development of dense understories, especially on bottomland sites (*31*). The consequence of understocking on bottomland sites can be costly in understory control or in lengthening the rotation. Much remains to be learned about composition control in bottomland hardwoods.

YELLOW-POPLAR

Though the seed-tree method has been proposed for reproducing yellow-poplar, there appears to be little justification for the method in the light of recent knowledge (*9,4,19*). Yellow-poplar seed remains viable for several years in the forest floor, so successive seed crops accumulate in the litter and germinate when moisture and temperature conditions are right. During a period of at least 2 or 3 weeks before germination, yellow-poplar seed must be continuously moist. This is why a scarified seedbed is best for yellow-poplar. Normally seed in and on litter dries out quickly after rain and cannot germinate. On a scarified seedbed the seed is in contact with mineral soil, which does not dry out as fast as the litter. Some seed is actually covered by mineral soil, and its chance of staying moist during the critical germination period is even better.

Yellow-poplar seed trees are not necessary as insurance against accidental fire or a dry spring. If yellow-poplar seedlings do not develop the first year after cutting, the seedbed deteriorates through the growth of weeds, shrubs, and other tree species. The possibility of second- or third-year establishment is remote. New seedlings do germinate the second and third year after cutting, but they cannot compete with the advance growth.

Scarification from normal logging is ample for preparing yellow-poplar seedbeds. Horse-logging in an Indiana clearcut scarified 17 percent of the area and there were enough yellow-poplar seedlings to stock the entire area although the seed trees were scattered. Undisturbed seedbeds with an excellent seed source produced only 3,000 yellow-poplar seedlings per acre after a heavy cut compared to 30,000 seedlings per acre in the scarified areas (*12*). In this case logging scarified 27 percent of the areas, and 82 percent of the quadrats were stocked. However, scarification in addition to logging may be good insurance in areas with widely scattered seed trees.

With a good seed source, disking or burning was not essential to obtain a good catch of yellow-poplar seedlings in New Jersey and Maryland (*19*). Undisturbed seedbeds had satisfactory stocking on practically all study areas. In this study burning was found to be just as effective as scarification in providing a suitable seedbed. Destruction of the current seed crop by

burning was further proof that yellow-poplar seed remains dormant in the duff.

Good stands of yellow-poplar reproduction have followed cuttings made throughout the year. For example, a summer harvest produced 6,000 yellow-poplar seedlings per acre and a winter harvest 10,000 per acre.[1] The area had a good seed source. Spring scarification produced as many seedlings as fall scarification in an Indiana test. However, in a date-of-scarification study during the growing season, June, July, and August treatments produced fewer seedlings than May treatment. Most seed in the summer-scarified plots did not germinate until the following spring, and the new seedlings were too small to compete with the advanced vegetation. So in areas with a poor yellow-poplar seed source, summer logging should be avoided.

The difficulty of controlling honeysuckle in bottomland yellow-poplar sites is typified by experience reported from South Carolina (*3*). Because of past experience with honeysuckle, the harvest area was broadcast-sprayed with herbicide for 2 years after cutting. Top and root kill were good, but vigorous new honeysuckle seedlings developed from seed stored in the litter. Yellow-poplar seedlings were released once a year for 5 years, but over half of the seedlings were dead within 5 years regardless of release. And the competitive position of released seedlings was not improved. Pre-emergence herbicides were suggested as a possible solution to the problem, but such a prescription would only work after the yellow-poplar seedlings are established. A mixture of 2,4-D-picolinic acid is recommended to control honeysuckle before regeneration cuts for yellow-poplar in the Northeast (*20*).

The economic practicality of understory control to encourage yellow-poplar establishment remains to be determined. A single application of ground herbicide to aid establishment would cost $15 to $20 per acre. Because of variable effects, the use of fire for understory control must be carefully evaluated before it is recommended.

Openings at least 1 acre in size are recommended for best yellow-poplar development. Smaller openings are inefficient due to the high percentage of the area shaded by the edges of the adjacent forest canopy (*19*). In central hardwoods, opening size from 1/8 acre to 5 acres did not influence the amount or

composition of reproduction 2 years after cutting.[1] However, opening size did influence growth. This same relation has been demonstrated for yellow-poplar in Tennessee.[3]

SWEETGUM

Sweetgum has been compared to yellow-poplar for many silvical requirements but always with the qualification that it is more tolerant of wet sites. For example, sweetgum represented 68 percent of the desirable understory seedlings on wet sites but only 27 percent on moist sites on the New Jersey Coastal Plain (*25*).

Experimental shelterwood cuttings on two small bottomland areas in New Jersey provided fairly good sweetgum stocking in the new stand (*31*). The original stand was composed of red oak, sweetgum, white oak, and red maple. Neither cutting area contained a sweetgum seed source, but abundant seed was supplied by trees adjacent to the plots.

Recent research shows that root sprouts from preexisting buds are important for sweetgum regeneration in the Piedmont of Georgia (*18*). This has been substantiated by a seed-tree cut in a loblolly pine-mixed hardwood stand in coastal South Carolina, where sprouts accounted for much of the sweetgum in the new stand.[4] Twenty to fifty root sprouts were found to be originating from individual parent trees.

Based on results of clearcutting pole-sized sweetgum stands in Mississippi, coppicing has been proposed for regeneration where pulpwood production is the primary goal (*17*). Six years after cutting, 800 to 900 sprouts per acre stocked the cut areas. Growth was rapid and no treatment was necessary after the harvest. It was suggested that many small even-aged patches of sweetgum in hardwood stands originate as sprouts.

Natural seeding cannot be discounted as a means of regenerating sweetgum. The invasion of agricultural land formerly

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[3]Smith, Henry W., Jr. *Establishment of yellow-poplar (Liriodendron tulipifera L.) in canopy openings.* Unpublished Ph.D. dissertation, Yale Univ. School of Forestry, 1963.

[4]Hook, Donald, Paul Kormanik, and Claud Brown. *Early development of sweetgum root sprouts in coastal South Carolina.* Unpublished manuscript, U. S. D. A. Forest Serv. Southeast. Forest Exp. Sta., 1968.

cultivated is ample evidence of the aggressive nature of this species through seeding. But we must take a closer look at new and old cuttings before we establish guidelines for regenerating sweetgum in a variety of situations.

BLACK WALNUT

Squirrels are responsible for practically all black walnut reproduction. Nuts are usually squirrel-planted within 300 feet of the seed source, so careful planning is needed to regenerate this species. Seed sources must be left adjacent to patch clearcuts or group-selection openings. In experimental harvest cuttings in Indiana, few seedlings were produced by the selection system but more than 200 new walnuts per acre made up a part of the new stand in a 5-year-old clearcut. Seed trees were sparse; the seedlings originated from seed on the area at the time of cutting or from squirrel-planted nuts from adjacent uncut timber. Needless to say, where the site is good enough, black walnut should be favored over all other species. However, it will take cleanings and weedings to bring a significant amount of walnut into the new stand.

In a study of small sawtimber-size walnut trees, openings created for crown release were ideal for the establishment of new seedlings. Evidently the right combination of seed source, canopy opening, and squirrel planting in excess of seed retrieved for food is needed to produce walnut seedlings. The odds against these factors combining to yield seedlings that can compete with fast-growing associate species help explain why walnut is only an occasional tree in the dominant stand.

IN CONCLUSION

Much research and practical experience have brought us to a point where we can give fairly good prescriptions for extensively managing oaks, yellow-poplar, and to a lesser extent sweetgum and black walnut. Unfortunately, extensive methods do not produce consistent results. In practice, results of harvest cutting are still erratic, and a system of intensive treatments remains to be defined and verified through controlled research and practical application. Of immediate concern are general areas of seed production and distribution, understory control, stocking, and management systems that integrate silvical requirements with owner objectives. Bottomlands, with their great productive potential, present our most difficult problems in regenerating the stand.

But we do not have to wait for the final word to make significant improvements in composition control. If we take the information we now have and temper it with basic ecological principles, we can begin to expect more than fortuitous juxtaposition. It is time we stopped taking pot luck in hardwood regeneration.

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ARTIFICIAL REGENERATION OF HARDWOODS

by R. L. McELWEE, *associate director, cooperative programs, School of Forest Resources, North Carolina State University, Raleigh, North Carolina.*

BEFORE DELVING into specifics, we need to consider the reasons for and the philosophy behind artificial regeneration. Irrespective of the methods used, most cultural practices employed in forest management, and particularly regeneration practices, are capitalized expenditures, which must be justified on need and future economic returns. Therefore it is imperative to take a look at the *aims* of regeneration.

Basic to sustained-yield forestry is suitable replacement of harvested stands. If maximum usable production is to be attained on any forested area, regeneration must not only be satisfactory in quality but must follow harvest without undue delay. Within the scope of the numerous economic policies, sites, and species used in forestry practice, many regeneration techniques can be employed, and none can be considered as universally suitable. Each stand should be re-established by the most efficient method consistent with the inherent quality of the particular site involved, the biologic capabilities of the species used, and the management goals and economic capabilities of the landowner.

It is deplorable but nonetheless true that regeneration of hardwoods was not even considered until relatively recently. Successful regeneration was, for the most part, a combination of fortuity and competitive tenacity of the species involved. Denuded and eroded areas, forests of cull individuals, stands composed largely of the less desirable species, all bear witness to failures of this combination and the lack of careful consideration and adequate provision of the silvical requirements necessary for obtaining and maintaining satisfactory regen-

eration. As a result, there are many thousands of acres of hardwoods to be restocked with thrifty regeneration of desired species before their productive potentials can be even partially realized.

NATURAL VS. ARTIFICIAL REGENERATION

As with conifers, hardwood regeneration can be accomplished by either natural or artificial methods. Though artificial regeneration may be more straightforward, it is in many ways more difficult and requires greater skill; it depends upon plant materials normally obtained outside the immediate planting site in the form of seed, nursery-produced seedlings or rooted or unrooted cuttings. Choice of method—natural or artificial—depends largely on biological characteristics of individual species tempered by individual experience, preference, and costs.

If artificial regeneration is to be used, it must be justified on the basis that less costly natural regeneration will not result in satisfactory stocking of desired species in a reasonable time. For certain hardwoods, particularly the lighter-seeded species, such a justification is often difficult. On better sites such as the alluvial floodplains of major and minor streambottoms and with a reasonable amount of assistance, natural regeneration of desirable species is generally so profuse that planting is not needed. Hosner and Minckler (*1960*), Johnson (*1961, 1964*), and others found conclusive evidence of adequate natural regeneration along stream bottoms. Minckler and Jensen (*1959*), Paton (*1946*), and Tryon and Carvell (*1958*) show similar promising results for uplands.

In his discussion of hardwood planting procedures, Johnson (*1966*) cites four justifications for planting hardwoods. They are: (1) to realize the benefits of tree improvement, (2) to modify and control species composition, (3) to alleviate prospective shortages, and (4) to prepare for future possible intensification of hardwood silviculture. A fifth justification that might well be included is to establish commercial hardwood stands on sites readily accessible for year-round logging.

ROLE OF ARTIFICIAL REGENERATION

Notwithstanding the present limited use of artificial regeneration of hardwoods, there are many situations and conditions that warrant its consideration. Consider, for example, stands that have been subjected to decades of high-grading, and that have few or no satisfactory seed sources. This fairly common condition requires deliberate and forceful methods if the sites are to approach their potential productiveness. Similar drastic measures are required wherever it is necessary to convert to a more desirable species mixture. In many instances an initial planting to obtain the desired species composition may be the only artificial regeneration required; and natural reproduction can provide the stands of succeeding rotations.

Tree improvement, a proven means of upgrading stand and tree quality, has limited potentials with natural regeneration. If genetic improvement is to be applied to hardwoods, artificial regeneration systems are dictated. Dependent upon species characteristics and demands, improved genetic stock must be established artificially by cuttings as in cottonwoods, by seed and grafted stock as in black walnut, or as nursery-produced seedlings. The degree of genetic variation, hazards of inbreeding, and ease of natural regeneration will determine the necessity of artificially regenerating succeeding stands.

Occasionally instances arise where it is desirable to convert from one species or species mixture to another having more economic potential. As an example, let me cite one of our recently initiated studies. Potential shortages of hardwood pulpwood can conceivably be alleviated by extending hardwoods to sites where they normally do not occur. By selecting and propagating appropriate individuals, a strain with commercial potential for nonhardwood sites will be developed. Our work here involves tests of sycamore on sites drier than those on which the species normally develops at adequate rates. Pulpwood rotations will be relatively brief, possibly 10 to 15 years. Though subsequent stands might be initiated by coppice, we feel that periodic planting will be necessary to keep the species dominant. The end result of this program will be successful conversion of sites presently supporting mixed

hardwoods or even some of the best pine to stands of sycamore to supply the increased demand for hardwoods.

Because of the fundamentally different reproductive habits among species of hardwood and between the hardwoods and conifers, I believe artificial regeneration of hardwoods will never become as extensive as it has with conifers. There will be continuing need for considerable artificial hardwood regeneration, however, making it necessary that techniques be developed and improved. We must, then, ask the question: "What do we now know concerning artificial regeneration of hardwoods?"

RECOMMENDATIONS

General

Of utmost importance in the successful use of artificial regeneration is the matching of species and suitable sites. Species-site interactions are being vigorously investigated for many valuable hardwoods, so our knowledge is constantly increasing. We know, in general, that of the four genera being discussed, yellow-poplar and black walnut are the most demanding in their site requirements, while sweetgum and certain oaks tolerate a wide range of site conditions well enough to provide satisfactory growth. Yellow-poplar usually grows best on fairly well-drained second bottoms and in mountain coves with uneroded deep soils, although in some sections good growth of yellow-poplar occurs on slopes up to ridgetops. Black walnut also has its best growth on deep, fairly well-drained soils of bottomlands, upland coves, and lower slopes (*Carmean 1966*). Best sweetgum growth is found on alluvial floodplains, but sweetgum can have satisfactory growth on somewhat poorer soils. Oak species vary greatly in habitat requirements: some of the best oaks, such as cherrybark, grow on fairly well-drained bottomland sites, while others such as chestnut oak are adapted to poor sites.

Nutrient amendments through fertilization offer real possibilities for increasing hardwood growth, but before such practices can become standard, biologic and economic potentials must be better understood. Forest fertilization of conifers has proven beneficial to growth and economically feasible in several countries, and the potential benefit of fertilization for

hardwoods seems frequently to surpass that for conifers.

Control of competition is necessary for the success of artificial regeneration, as it often is for natural reproduction. On some sites this may be achieved by elimination of cull trees through girdling or herbicide injection; but often mechanical site preparation such as blading, chopping, disking, and bedding—singly or in combination—is needed. On extremely wet sites water control can be beneficial if not mandatory for success.

Selection of the proper establishment technique is, of course, highly important. In general, the light-seeded species are most successfully established by planting seedlings or cuttings, while direct seeding is usually selected as the technique for heavy-seeded species.

Off-site planting and faulty planting techniques have been partially responsible for the failure or poor performance of many plantations, but poor seedling vigor may often be the basic reason. Many nurserymen have grown hardwood seedlings at densities similar to those for conifers: 25 to 30 per square foot. Recent trials show that a density of 7 to 12 per square foot produces the type of vigorous hardwood seedling that is most likely to survive and grow in height the first year after planting. For most hardwood species, best performance is usually obtained from seedlings that have root-collar diameters greater than 0.375 inch. Planting success may also be affected by nursery pruning of root or top, planting depth, and erectness of the seedlings; and these factors are being investigated.

In nursery production of all hardwoods, the beds should be pretreated by fumigation for weed control. Although expensive, it costs far less than hand weeding alone. Even with pretreatment, some hand weeding is necessary.

By Species

The methods described below are currently thought to be the best for individual species, although modifications may be needed to satisfy local conditions.

Sweetgum.—Fruits can be collected readily from felled trees or by climbing or shaking standing trees. Air-drying the fruits releases the seeds along with numerous aborted ovules, which can be removed by screening. The seed can be stored dry at

temperatures just above freezing, and then treated to 30-day stratification prior to sowing in nursery beds at densities that produce 15 per square foot.[1] Alternatively, seed can be stored at temperatures below freezing, and stratification can be eliminated.

Outplanting on moist sites should closely follow lifting from the nursery bed; and if storage is necessary, the seedlings must be kept cool and moist. The 1-0 seedlings can be refrigerated at temperatures between 35° and 40° F.

Full sunlight must be provided for established seedlings. Competition from grass can seriously affect growth during the first year and, like overhead shade from competing woody vegetation, can cause the failure of the plantation. Spacing will depend on the product to be grown, but we recommend spacings of 8 x 8 feet to 10 x 10 feet for pulpwood, and closer spacing down to 6 x 8 feet for sawtimber and veneer rotations.

Direct seeding on prepared sites is feasible in areas having plentiful moisture so that seed does not dry out (*McKnight 1965*). Although little experience is available, it is recommended that fall-sown seed not be stratified, though stratified seed should be used in the spring. Techniques of direct seeding are not sufficiently advanced to recommend this practice for extensive commercial use.

Yellow-poplar.—Seed cones are collected in early fall; after air-drying they are broken up by hand or mechanical means, and the individual carpels are removed from the cone axis. The seeds are stored in dry refrigeration or in moving water. If dry storage is used, a 60-day stratification should preceed spring sowing in the nursery. There are also recommendations for fall sowing of yellow-poplar seed in nurseries. Seed germination may be very low, often less than 10 percent, in part because of the large amount of inbreeding forced by the habits of honeybees effecting pollination.[2] Because of the low germination, seed is often sown so it completely covers the nursery bed to a depth of ½ inch. Germination tests will help in judging

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[1]Webb, Charles D. *A study of the effects of seedbed density on nursery stock quality of sweetgum (Liquidambar styraciflua L.) among open-pollinated progenies.* Unpublished report, U. S. D. A. Forest Serv. SE. Forest Exp. Sta., 1964.

[2]Taft, Kingsley Arter, Jr. *The effect of controlled pollination and honeybees on seed quality of yellow-poplar (Liriodendron tulipifera L.) as assessed by x-ray photography.* Unpublished M.S. thesis, N. C. State Univ. School Forestry, 1962.

the desirable thickness of sowing. If germination is better than expected, hand thinning should be used to reduce seedling density to 15 per square foot.

Outplanting on well-prepared suitable sites should be at spacings that provide 60 to 90 square feet of area per seedling. Direct seeding of yellow-poplar has not been sufficiently successful to recommend it for general use.

Oak.—Artificial regeneration of oak is beset with problems at every step. Seed collection is difficult: the most satisfactory way to obtain seed is from felled trees or by shaking. I know of no absolute means of telling when seed is sufficiently mature to collect, although the yellowish-orange color of the endosperm seems to be the best gage for many species. The use of tree shakers offers real possibilities for gathering acorns, but the timing must be carefully judged. Seed collected from the ground after natural seedfall contains a high percentage of weevil-damaged acorns, especially among those falling first. Visual detection of damaged acorns is costly, but is preferable to flotation tests.

Acorns are stored in refrigeration at high humidities, but often germinate in storage. Care must be taken not to damage the radicle when planting. Nursery seeding can be made in drilled rows, with seeds covered by ¼ to ½ inch of soil and mulched with pine needles; or the seeds can be broadcast before rolling and mulching the seedbed. Seedling densities should be held to 10 or less per square foot.

For outplanting, seedlings should be husky, with large diameters and stems 12 to 15 inches long. Seedlings of this size plant well by hand or machine. Removal of all vegetation from the planting site to assure full sunlight is necessary for best establishment of oaks. However, there has been relatively little experience in planting oaks.

More effort has gone into development of direct-seeding techniques, but with varying success. Destruction of seed by rodents has been the chief cause of failure in direct seeding. Use of repellents, screens, or other protective measures has proven necessary in some instances and not in others, depending upon the size and tenacity of the rodent population. In considering the status of our ability to artificially regenerate oaks, I can only conclude that we have much to learn before we can

confidently undertake such regeneration on a commercial scale.

Black walnut.—Of the four genera, walnut is the only one for which I believe artificial regeneration is the most productive method of establishment. The potential high value, cultural requirements, and relative scarcity of black walnut in natural stands justify higher regeneration costs than for other species.

Walnut seed is fall-sown to produce densities of 10 to 15 seedlings per square foot. Nuts are covered with an inch of soil and mulched. Seedling quality standards have been devised; they include minimums for both stem caliper and height. As with all hardwood seedlings, care must be taken to avoid the drying of roots.

Outplanting should be on well-prepared suitable sites where control of herbaceous as well as woody vegetation is practiced. Extreme care should be taken in planting; auger holes should be used on some sites. Spacings vary according to site, but I have found no recommendations for planting closer than 8 x 8 feet in pure stands, and some recommendations call for very wide spacings. Walnut is also planted in mixtures with other hardwoods, particularly oak and ash. For development of quality trees, intensive culture in pruning and release should be started at an early age. Some plantations may be made with grafted stock at very wide spacings, and may be managed as a horticultural rather than a forestry enterprise.

As with the oaks, direct-seeding success depends upon rodent control. Fall sowing of unstratified nuts or spring sowing after stratification is recommended, with nuts being placed 2 to 4 inches deep at spacings ranging from 8 x 8 to 14 x 14 feet. Sites must be well prepared, and cultivation equipment must be available. However, until the development of effective rodent-control practices, little consistent success seems possible from direct seeding.

For Maximum Gain

The importance of seed source and seed-tree selection have not been mentioned, but both proper seed source and the selection of superior individuals are mandatory if we are to realize maximum gains through artificial regeneration. Artificial regeneration of hardwoods is an expensive undertaking, because site preparation and seedling costs are high. We need to strive

for maximum yields in gross production, quality, or both if artificial regeneration of hardwoods is to be economically justified.

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EFFECTS OF DENSITY, THINNING, AND SPECIES COMPOSITION ON THE GROWTH AND YIELD OF EASTERN HARDWOODS

by SAMUEL F. GINGRICH, *project leader in mensuration research, Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Columbus, Ohio.*

THIS IS A SUMMARY of present knowledge about the effect of density, thinning, and composition on the growth and yield of eastern hardwood forests—with particular emphasis on recent literature based on research.

The eastern hardwoods include the upland oaks type; and the bottomland hardwoods type, in which several oaks predominate and where such overstory trees as yellow-poplar (*Liriodendron tulipifera* L.), sweetgum (*Liquidambar styraciflua* L.), and black walnut (*Juglans nigra* L.) are the desired species. These types cover more than 200,000,000 acres of commercial forest land in an area that extends from southern New England to the southern Lake States to Georgia and the Gulf States.

STAND DENSITY IN HARDWOODS

Most hardwood stands, whether even-aged or uneven-aged, develop naturally at high density. In the absence of thinnings or catastrophic events, the growth rate of individual trees is slow, and the stand mortality is high. While much has been said about the understocking of hardwood stands, this general condemnation of understocking usually refers to an understocking of high-quality trees or desired species and not to stocking per se.

One has only to compare the stand development of natural stands (as projected in yield tables) with the results of thinning experiments to obtain some idea about the effects of stand

density on tree growth. Many of the desirable intolerant species such as black walnut, yellow-poplar, and the ashes (*Fraxinus* sp. L.), unless able to maintain a dominant crown position, succumb to natural mortality. The highly competitive growing conditions in dense stands produce low-vigor trees that grow far below their potential rates. Overstocking in hardwoods may be more damaging than understocking.

There are other conditions of hardwood density where different problems prevail. Many hardwood stands have been high-graded, burned, grazed, and generally mismanaged for decades. Repeated harvesting of high-quality hardwoods has caused stand quality to deteriorate. A cull volume ranging from 40 to 60 percent (*9*) is common in many areas. Low densities under these conditions compound the problem, and the desired silvicultural practices range from some type of removal cut to a policy of wait-and-see.

THINNING HARDWOODS

Ask any forester what constitutes a managed forest and his answer will probably include thinning. Thinning is described in most textbooks as a necessary forest-management activity. Much has been written about the subject. However, of the published information that tells how thinning affects growth of hardwoods, little is based on experimental results. And almost nothing has been published about the economics of thinning.

For the sake of this discussion, thinnings will be considered as the removal of trees in immature stands where reproduction is not an immediate objective. There are generally two different philosophies about thinning: thin for future benefit, or thin for present gain. The first emphasizes improvement of the residual stand; it may be a precommercial thinning or a commercial thinning. The quality, vigor, and spacing of the trees in the residual stand are given primary consideration. The second emphasizes the economic feasibility of the thinning operation; the condition of the residual stand is of only secondary importance.

Biologically, and perhaps economically, the two philosophies seem to conflict. That is one reason why it is difficult to generalize about thinning. However, opinions about thinning do

not always mean disagreement about basic principles. Often they represent the varying circumstances of a situation.

What is the present state of knowledge about thinning hardwoods? First, consider precommercial thinnings. There is broad support in favor of precommercial thinnings of hardwood stands among silviculturists (*2, 11, 13, 15*). Young, vigorous hardwood stands with desirable species composition on better-than-average sites would appear as ideal conditions for precommercial thinnings. During the first quarter of a rotation there is good opportunity to alter species composition and select quality stems. This is also the time to improve tree spacing and to maintain crown vigor.

The case against early thinning generally rests on the effect of lower densities on stem quality, particularly the development of epicormic branches from suppressed buds on merchantable stems. This presents a dilemma to the silviculturist whose objective is to grow high-quality timber.[1]

On the one hand he is forced to grow large timber fast, risking a reduction in quality; and on the other hand he is keenly aware of the price differential between high- and low-quality timber. And in some cases the only justification for thinning is higher quality yields. Thinning hardwoods may not be a matter of volume production only but a compromise between high-volume production and high financial return.

First thinnings in high-density hardwood stands do not always produce the expected growth response. Because such stands contain low-vigor trees, dense clumps, and mixed species, the first thinning may actually result in a net growth deficit. Holcomb and Bickford (*6*) suggested that spacing, soundness, and vigor of residual trees may be more important than relative growth in the first cutting or two. Haney (*5*) reported that unthinned white oak clumps (*Quercus alba* L.) on poor sites in the Virginia Piedmont produced 108 percent more merchantable volume than clumps that were thinned to a single remaining stem. Tepper and Bamford (*19*) found that low thinnings in oak-sweetgum stands on poorly drained sites in New Jersey did not increase the 10-year growth of either the

[1]Normal yield tables for upland oak *(17)* show that on site index 70 only 8 percent of the trees reach the minimum size required for No. 1 hardwood sawlogs in 100 years.

entire stand or of selected crop trees. Trimble and Tryon (*22*) found that crown encroachment into openings cut in 40- to 55-year-old Appalachian hardwood stands was surprisingly slow for red oak (*Quercus rubra* L.) and yellow-poplar. To obtain maximum benefits from thinning, Roach and Gingrich (*16*) suggested that first thinnings should be made before the stand is 60 to 70 years old on medium sites.

Substantial growth responses from thinning have been reported in the South and on better than average sites in the North. Putnam *et al.* (*13*) reported that diameter growth of individual trees on average bottomland sites might be increased by 30 percent under intensive management and close to 40 percent if the sites were occupied by entire stands of the more desirable species. Apparently results from thinning hardwoods depend more on *species composition, tree vigor,* and *potential stem quality* than merely the growth responses due to reduction of stand density.

Species Composition

The intimate mixture of species in most hardwood stands is a complicating factor in growth studies. Most foresters have favored one species over another on the basis of commercial value or management goals. Very little is known about the biological performance of various species mixtures in the thinned stands.

The number of possible species mixtures is so large that it is impractical to study the effects of species composition in much depth by using permanent replicated plots. But the relative diameter growth rates of hardwoods are generally known.

The differences are so great among associated species that a thinning schedule aimed at increasing the number of fast-growing species would appear to produce a substantial yield bonus over a schedule where species composition is ignored. Putnam *et al.* (*13*) report 10-year diameter growth rates for 11 southern hardwoods ranging from less than 2 inches to more than 6 inches under similar stand conditions. McIntyre (*12*), Trimble (*20*), and Gingrich (*4*) have published growth rates for the principal oak species. Their studies show that trees in the red oak group will grow much faster than trees in the white oak group under the same density and site conditions.

Tree Vigor

The lack of conclusive results in hardwood thinning studies is often due to a lack of knowledge about residual tree vigor. Too often the forester has assumed he could perform growth miracles by the thinning process alone, while giving little attention to the growth capabilities of the trees released by the thinning. Oaks, in particular, can survive many years under high density conditions at growth rates as low as 15 rings per inch. Many such oaks do not have the crown or root systems to respond to the thinning release.

It is becoming more evident that many hardwoods that have endured long periods of high competition are not good candidates for thinning. Weitzman and Trimble (*24*) developed four vigor classes for northern red oak and chestnut oak (*Quercus prinus* L.) based on several crown characteristics. Their studies showed that, for a given diameter class and site quality, a high-vigor tree will produce five to six times more volume growth than a low-vigor tree. Holcomb and Bickford (*6*) found similar results with yellow-poplar vigor classes. Walters (*23*) found that the best indicators of the growth potential of oak and yellow-poplar seedlings are their immediate past growth and present crown position. Carmean and Boyce[2] found that the fastest growing dominant trees in upland oak forests maintain a live crown length that is about two-thirds of total tree height.

Potential Stem Quality

Another important factor in thinning hardwoods is the potential stem quality. Like vigor, a system of classifying stem quality will provide valuable guidelines for marking. The grade of hardwood logs and trees depends on the clear space between defects rather than on the size of defects.

Therefore one of the major goals of stand manipulation for quality production should be to develop a moderate number of stems per acre that have a good proportion of clear bole (*25*). Ward (*26*) presented a strong case for maintaining high-density stands that will favor natural pruning. He found that approximately 50 percent of the variation in clear-volume index of

[2]Carmean, Willard H., and Stephen G. Boyce. *Quality of site affects the quality of oak logs.* In press. U. S. D. A. Forest Serv. North Central Forest Exp. Sta.

individual red oak trees was directly proportional to the degree of crown competition or stand density around the sample tree. Carmean and Boyce[2] also recommended high initial stand densities in very young upland oaks stands to avoid excessive growth of knotty annual rings.

Farther south, Kormanik and Brown (*8*) have done considerable research on some of the physiological aspects of epicormic branching in sweetgum and yellow-poplar. They believe that associated with the phyllotaxy of the tree there is a physiological control that governs the eruption of suppressed buds. They anticipate methods of controlling epicormic branching in some of the southern hardwoods. Weitzman and Trimble (*24*) indicated that some species clear up faster than others under identical conditions of age and size, suggesting that species appear to have a built-in grade potential just as they have a built-in growth potential. Holsoe (*7*) found that difference in the clear-bole length between thinned and unthinned 20-year-old white ash stands disappeared by age 40.

Most research confirms Smith's (*18*) philosophy that dominant trees with full vigorous crowns are less likely to develop new branches after exposure than those that have unthrifty crowns or are from lower crown classes. The best way to avoid epicormic branching is to develop good crowns by thinning and to maintain crop trees as dominants throughout their lives. Boyce (*2*) offered one solution to the problems of epicormic branching and quality. He recommended butt-log silviculture on good sites where the emphasis is on fast growth of a few well-spaced superior trees that will develop large crowns.

It is apparent that for thinnings to be more effective, a system of tree classes that incorporates species response, vigor, and quality potential is necessary. Investments in cultural practices could be made with greater assurance of improving timber quality. Boyce and Carpenter (*3*) have published provisional grade specifications for hardwood growing-stock trees (d.b.h. 7 to 15 inches). They developed a technique based on a simple count of surface-indicator defects on the butt log with allowance for crown class and scaling deduction—a technique that is useful in determining the probability of a given tree producing a certain grade of sawlog. Too often the assumption has been made that the mere removal of rotten or

defective trees will increase the number of grade 1 logs produced by a stand. However, it is more efficient to concentrate cultural efforts and costs on selected trees rather than on whole stands in the hope of improving the quality of the residual trees.

YIELDS

Yield information based on long-term studies of managed hardwood stands is scarce. Normal yield tables are availabe for upland oak (*17*) and yellow-poplar (*10*). But the limitations of normal yield tables are well known. Baker (*1*) gave an example of the erroneous reasoning about yield from thinning. He said: "On the one hand, foresters have computed growth of stands by comparison with yield tables by direct proportion; reasoning that if stand A has 80 percent of normal basal area, its growth is 80 percent of the yield table value. And on the other hand, in all seriousness, they recommend thinnings to remove perhaps 20 percent of the basal area to increase growth. Obviously something is seriously at fault."

An attitude prevails today among silviculturists—encouraged to some extent by economists—that the science of forestry will be enhanced considerably when yield tables or equations for managed stands become available. However, several factors should be recognized.

First, the oldest growth studies in the hardwood types discussed here are no more than 20 years old—only a fraction of the anticipated rotations. Second, the problem of quantifying yields for various management schedules is compounded by the kinds of information that could be generated from any particular hardwood type. Realistically, it is impossible to expect anyone to publish in one neat package yields in numerous units of measurement for all combinations of thinning schedules, species mix, management goals, by site quality, utilization standards, and so on. I submit that even if we had all-purpose yield information based on rotation-length studies, our planning horizons would still be limited to 10 to 20 years.

Some yield estimates are available for rather localized timber conditions, and considerable research effort in this is under way throughout the hardwood region. Roach (*14*) estimates that

rotations for upland oak in the Midwest can be reduced by 40 percent where thinning is begun early in the life of the stand. Trimble and Mendel (*21*) have synthesized yield data for northern red, white, and chestnut oaks. They have developed rates of value increase and financial maturity tables by site index and tree vigor classes for both volume growth and quality changes.

The need for more hardwood growth and yield research has been promoted by several trade journals, numerous hardwood associations, and industries. Many universities have embarked on basic investigations of hardwood growth research. The U. S. Forest Service has a research program for hardwood stand-density studies. All this gives some promise of more and better yield information soon.

DISCUSSION

In analyzing the current information about growth and yield of the eastern hardwoods, we can see great promise in some of the research being done. However, we still need a better understanding of the basic principles of tree growth, particularly growing space, tree vigor, and potential stem quality.

Though the regulation of stand density offers good opportunity to increase yields, other factors must be considered. The difference in growth between a low- and high-vigor tree might be considerable greater than the difference in growth due to density alone. Differences in growth due to site quality may also be greater than those due to stand density alone. Rates of return are several times higher when quality increases are considered than when only volume growth is considered.

The magnitude of these differences is extremely high among hardwoods, and these factors need to be given more consideration when thinning hardwoods. One of the most important attributes of a hardwood silviculturist is his ability to recognize quality or potential quality of the young tree.

Finally, the most useful information from growth studies would be stand tables resulting from different types of thinning schedules. These tables will provide the basic information for any potential customer to make the necessary conversions to whatever unit he may want.

There are some crucial voids in our knowledge of stand density, thinning, and species composition as they relate to the growth and yield of hardwoods. Some of these voids have been recognized and are under study. Mensurationists are beginning to gain more insight into the components of stand growth through the study of individual trees, and biometricians have had some success in developing nonlinear growth models for mixed stands. Silviculturists, mensurationists, and economists are realizing more and more the need to utilize current growth information, incomplete and imperfect as it may seem, in the resource decisions that must be made now.

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SITE QUALITY FOR EASTERN HARDWOODS

by WILLARD H. CARMEAN, *project leader in site requirements for northern hardwood forest species, North Central Forest Experiment Station, Forest Service, U. S. Department of Agriculture, St. Paul, Minnesota.*

QUANTITY OF YIELD for hardwoods, as for conifers, is greatly influenced by site quality. Quality of yield also varies greatly with site quality. On good sites large volumes of high-grade hardwoods can be grown in relatively short rotations; in contrast, poor sites produce only small amounts of low-grade hardwood products and rotations are long. Accordingly, good hardwood management requires that site quality be carefully identified so that each parcel of land may be managed to grow the hardwood species and products it is best adapted to producing. Furthermore, knowledge of hardwood site quality is necessary so that heavy investments are restricted to excellent sites capable of producing large volumes of high-grade timber—prime hardwood timber that can command high prices for valued products such as furniture and veneer.

Unfortunately, we have only meager information about the site requirements for the many species of valuable eastern hardwoods. We have only limited knowledge about yields of hardwood species at different levels of site quality, or at different intensities of silviculture. However, we do have considerable information about site quality for many of our eastern hardwoods. This scattered information gives us a general picture of the variation in site among various hardwoods and, further, about the soil and topographic features often related to site changes for hardwoods.

DIRECT MEASUREMENT

The most widely accepted method for evaluating site quality in the United States is the direct estimation of site index. Height and age measurements from dominant and codominant trees are used with published site-index curves to estimate how tall trees will be at an index age—usually 50 years for eastern hardwoods. Site index is then related to yield tables to estimate growth and yield of forest stands at various stand ages. A total of 26 different site-index curves have been published for 16 eastern hardwood species (table 1), and many of these curves have been reproduced in a summary publication (*32*).

The site-index method is simple and easy to apply when suitable forest trees are available for the required height and age measurements. However, in many hardwood forest areas suitable trees are lacking because stands may be uneven-aged, poorly stocked, too young, damaged by fire or heavy grazing, or may have been subjected to various intensities of past cutting. Satisfactory site-index measurements can be taken only from dominant and codominat forest-grown trees that have been free-growing and uninjured throughout their lives. Such trees most commonly occur in even-aged fully stocked hardwood stands that have not been disturbed by past cutting. For example, in the Central States many even-aged upland oak stands occur in areas formerly clearcut for charcoal. Dominant trees in such even-aged oak stands are very well suited for site-index measurements, just as are dominant trees in even-aged conifer stands.

Most trained foresters should know how to select proper trees and stands for site-index measurements. But errors in site-index estimation still may occur even when suitable forest trees are available for measurement. These errors occur when regional harmonized site-index curves do not accurately portray the variable patterns of tree height growth that are found within many large forest regions (*17*).

Many of our important hardwoods, such as upland oaks and yellow-poplar, occur over extremely wide geographical areas. Within these large areas there are great differences in soil, topography, and climate; and these differences may cause great variation in site quality. However, in addition to site-quality variation, these differences may also be associated with variable

Table 1.—Site-index curves for eastern hardwood forest species

Tree species	Area	Reference
Upland oaks	Eastern States	Schnur (*58*)
	Piedmont & South Appalachians	Olson (*50*)
Red oak	Lake States	Gevorkiantz (*29*)
Hickory	Central States & Appalachians	Boison & Newlin (*7*)
Yellow-poplar	Central States & Appalachians	McCarthy (*45*)
	Piedmont & South Appalachians	Beck (*6*)
Sugar maple	Vermont	Curtis & Post (*19*)
	Vermont	Farrington & Howard (*26*)
	Vermont	Hawes & Chandler (*36*)
	New York	Farnsworth & Leaf (*25*)
Red Maple	Connecticut & Massachusetts	Foster (*27*)
Yellow birch	Vermont	Curtis & Post (*19*)
White ash	Vermont	Farrington & Howard (*26*)
		Curtis & Post (*19*)
Black walnut	Central States	Kellogg (*41*)
Black locust	Central States	Kellogg (*42*)
	Long Island	Hopp & Grober (*39*)
Sweetgum	Maryland	Trenk (*62*)
	Southern alluvial soils	Winters & Osborne (*68*)
	Mississippi Valley	Broadfoot & Krinard (*12*)
Cottonwood	Mississippi Valley	Broadfoot (*8*)
	Central States	Neebe & Boyce (*48*)
Cherrybark oak	Mississippi Valley	Broadfoot (*9*)
Water oak	Mississippi Valley	Broadfoot (*10*)
Swamp blackgum and tupelogum	Southeastern Georgia	Applequist (*1*)

patterns of tree-height growth. Trees may follow entirely different patterns of height growth in order to arrive at the same height at 50 years—that is, the same site index. Accordingly, the height-growth pattern portrayed in a single set of regional site-index curves may not accurately represent the diverse height-growth patterns actually found in widespread geographical areas.

Considerable evidence is available to confirm that variable height-growth patterns exist on different sites, soils, or in different portions of large forest regions (*17*). This evidence includes:

- Contrasting harmonized site-index curves where two or more sets of curves are developed for different portions of the range of a particular species: for example, the three sets of site curves for upland oaks listed in table 1 show definite contrasts in patterns of tree-height growth.

- Periodic height-growth measurements from permanent study plots that show height growth different from the growth predicted by harmonized site-index curves.

- Soil-site studies that indicate variable height-growth patterns on contrasting soil or topographic conditions.

- Stem-analysis studies that reveal actual height growth for trees growing in areas of contrasting site quality. These stem analyses frequently reveal polymorphic height-growth patterns decidedly different from the patterns portrayed by conventional harmonized site-index curves.

Errors in site estimation due to faulty site curves may be particularly large for very old or very young forest stands. Of course, no error occurs when trees are 50 years old because their present height also is site index. But site-curve errors become progressively greater with increased number of years from the index age of 50. Accordingly, when we are uncertain about the applicability of regionwide site curves we should measure trees as close as possible to 50 years. Trees ranging from 35 to 65 years are usually acceptable.

Variable patterns of tree-height growth mean that we must carefully evaluate the applicability of all regionwide harmonized site-index curves. In many cases we may find that a single set of site curves cannot adequately express the different growth patterns for tree species that have wide geographical ranges, or that have wide ranges of site quality. Thus several sets of local site-index curves may be needed to describe more accurately the pattern of tree-height growth produced by local soil, topographic, and climatic conditons. Polymorphic site-index curves based upon stem-analysis techniques are recommended.

Species Comparisons

Many stands suitable for site measurements may not contain the tree species for which site-index estimates are desired. Dominant trees of several species may be present, but no usable trees of the particularly desired tree species may occur. For such stands we can estimate site index by using the tree species that are actually present. Then species-comparison graphs can be used to convert site index of the measured trees to site index of other desired tree species. Species-comparison graphs have been published for hardwoods in the southern Appalachians (*23*), for the Piedmont (*49,51*), for Vermont (*20*), and for white pine and red maple in Connecticut and Massachusetts (*27*). Site-index ratios among various species of oak have been listed by Trimble and Weitzman (*64*).

Species comparisons are a very useful means for extending the application of direct site-index estimations. Additional comparison studies are needed covering additional tree species and forest areas. These comparisons are particularly helpful in judging which species is most productive on particular sites. However, we should bear in mind that the comparisons are based on tree-height growth alone. Therefore we should also base the choice of species on additional comparisons, especially of volume and value of yield, where possible.

INDIRECT METHODS

Measurements of site index from standing trees are very satisfactory whenever suitable trees occur, and when we have suitable site-index and species-comparison graphs. But the land may be devoid of trees, or trees may have been injured by fire

or heavy grazing, stands may be too young or may be uneven-aged, or indiscriminate cutting may have removed the free-growing dominant and codominant trees needed for direct site-index measurements. Therefore methods of site evaluation are needed that are applicable to all forest land regardless of the composition or condition of existing cover.

Three indirect methods of estimating site index have been developed.

Understory Vegetation

Plant indicators of forest site quality are widely used in northern Europe and Canada. However, the method has received relatively little attention in the United States. Understory plant communities are relatively simple in northern coniferous forests, and only two or three species are usually dominant in the understory on sites of a particular quality. In contrast, hardwood forests in more southerly latitudes have a much greater number of understory species. These species may occur in a great variety of combinations; and many of them occur over a broad range of site quality. In addition, the plant-indicator method may be difficult to apply in recently disturbed forests or in forests having great contrasts in composition and stocking. And this method cannot be used during dormant seasons if it is based on herbaceous plants.

Despite these limitations there are certain understory species that occur on a rather narrow range of site quality—that is, species that have narrow ecological amplitudes. And these relationships could undoubtedly be better defined if quantitative ecological techniques are used. But because of complexities in composition, it is unlikely that site quality for eastern hardwoods can ever be defined on the basis of only a few understory plant species. Instead, on each site we would probably have to rely on a spectrum of several species of key plants, each of which will require an evaluation for abundance (*38*).

The plant-indicator method can be a useful supplement to other site-evaluation methods. Understory vegetation may be particularly useful in mapping forest soils and site quality because understory vegetal changes frequently indicate boundaries between soil and site-quality classes.

Soil Surveys

Soil surveys for agricultural lands in the United States have been made for more than 60 years. At first, attention was given only to productive agricultural lands. Rough broken land, suitable only for tree growth was either ignored or received only superficial attention. But in recent years increased attention has been given to forest lands, and in most states modern soil maps are being prepared for all lands, both agricultural and forest. The U.S.D.A. Forest Service has active soil-inventory programs under way for National Forest lands, using methods similar to those of the National Cooperative Soil Survey (*57*).

Most recent forest-soil surveys contain tables that give interpretations of site quality for forest growth, as well as for other features including competition, regeneration potential, trafficability, disease hazards, etc. (*43,57*). Some of these interpretations are based on quantitative data gathered in the course of the soil survey. However, in many cases interpretations are based on limited data or on the subjective opinions of soil scientists and local foresters. Accordingly, such interpretations are more art than science, because they depend on the experience and intuitive ability of individual soil scientists and foresters. Probably in many cases these subjective interpretations are satisfactory. However, acceptance of these assumptions is largely a matter of faith until research can provide firm facts baded on carefully collected and analyzed measurements.

Soil-survey reports often list site-index averages for the many soil-taxonomic units described in the soil survey. But these individual averages are frequently based on few actual site measurements. Moreover, close inspection of the basic data often shows that site index varies widely within soil units while, in contrast, the averages of most units are strikingly similar. Thus, the logical conclusion is that similar averages and excessive site variation within soil units often limit the usefulness of soil-taxonomic units for site-quality classification.

Excessive site variation within soil-taxonomic units has been shown for black oak in southeastern Ohio (*13*), for yellow-poplar in southwestern Virginia (*66*), for yellow-poplar and upland oaks in the southern Appalachians (*40*), and for sugar maple in New York.[1] Probably much of this observed site variation is related to certain soil and topographic features that vary widely

within soil-taxonomic and soil-mapping units, but may not be well described in the definitions of these units. Such soil and topographic features include surface-soil depth, texture and stone content of the subsoil, slope position and steepness, slope shape, and aspect.

Obviously, if site quality is to be accurately classified, the classification of soil types or soil phases must be based on the soil and topographic features that are closely related to differences in forest-site quality. The many soil-site studies published for hardwoods (tables 2 and 3) and for other forest species (*18,56*) can provide this information. These soil-site studies not only quantitatively pinpoint the significant soil and topographic features, but also express the magnitude of the site changes associated with each of these significant features. Ideally this information should be obtained for each study area before soil surveys are made, so that features closely related to site quality can be included in the definitions of mapping units for the soil survey.

The classification system of soil surveys is flexible and provides for the addition of phases or subdivisions needed to serve the utilitarian objectives of users. Accordingly, designing phases or subdivisions that permit classification of forest-site quality can easily be done once we know the specific soil and topographic features that should be included. But close coordination between soil-site research and soil survey is needed if the most effective breakdown by phases or subdivisions is to be developed.

For example, excessive variation of oak-site quality occurred in the soil-taxonomic units described for upland soils of southeastern Ohio (*13*). Soil-site studies pinpointed the important soil and topographic features that were related to site changes in this area (*14*). These soil-site results were then used as a basis for constructing topographic phases that better defined differences in oak-site quality (*16*).

Soil Site Studies

Forestry research has accumulated much information about relationships between tree growth and features of tree environment including soil, climatic, and topographic features (*18,56*).

[1]Berglund, J. V. *The utility of the National Cooperative Soil Classification System in the management of New York sugar maple stands.* Unpublished manuscript.

Table 2.—Soil-site studies for upland oaks in the East

Area	Topographic features	Soil features	Reference
Connecticut	Slope position	Total N	Lunt (*44*)
Rhode Island	Slope steepness	Surface soil depth Soil texture Soil drainage	McGahan et al. (*47*)
S. Michigan	Slope position Slope steepness	Subsoil texture Subsoil moisture	Gysel & Arend (*31*)
NE. Iowa	Aspect Slope steepness	Soil depth	Einspahr & McComb (*24*)
Arkansas Ozarks	Slope position Aspect	Soil depth Parent material	Arend & Julander (*2*)
SE. Ohio	Slope position Aspect	Surface soil depth	Gaiser (*28*)
SE. Ohio and S. Indiana	Slope position Aspect Slope steepness Slope shape	Surface soil depth Subsoil texture Subsoil stone content	Carmean (*14,16*) and Hannah (*33,34*)
Appalachian Mts. (West Va.)	Slope position Aspect Slope steepness	Soil depth Parent material	Trimble & Weitzman (*64*) Trimble (*63*) Yawney (*69*)
Ridge and Valley (W. Va. & Md.)	Slope position Aspect	Depth of A+B pH of A2	Yawney & Trimble (*70*)
Appalachian Mts. (N. Carolina)	Slope position Aspect	Surface soil depth Surface soil texture Humus type	Doolittle (*22*)

Appalachian Mts. (Georgia)	Slope position Aspect Slope steepness Elevation	Surface soil texture	Ike & Huppuch (*40*)
Piedmont (Va., N. & S. Carolina)	Slope position Slope steepness	Org. content of A1	Della-Bianca & Olson (*21*)
N. Alabama	Slope position Slope length Aspect		Smalley (*60*)
N. Mississippi and W. Tennessee	Slope position	Depth to least perm. horizon Surface soil texture 15 atmos. tension of least perm. horizon	McClurkin (*46*)

Table 3.—Soil-site studies for other upland hardwoods in the East

Species and area	Topographic features	Soil features	Reference
Yellow-poplar:			
Central States	Slope position Aspect	Depth of A1 Depth to subsoil Surface soil texture Subsoil drainage	Auten (*4*)
W. Indiana		Depth of A1 Depth to claypan or mottling	Tryon et al. (*65*)
S. Illinois		Depth to fragipan Depth of organic matter	Gilmore et al. (*30*)
New Jersey	Slope position	Depth to mottling Depth to subsoil Subsoil texture	Phillips (*52*)
Piedmont (Va., N. & S. Carolina)	Slope position Latitude	Depth of A1 Organic content of A1 Surface soil texture	Della-Bianca & Olson (*21*)
W. Tennessee	Slope position Aspect	Depth to gley Drainage	Hebb (*37*)
Appalachian Mts. (Georgia)	Slope position Elevation		Ike & Huppuch (*40*)
Sugar maple:			
N. Michigan		Soil depth Soil texture Stone content	Westveld (*67*)
Vermont	Elevation Aspect Latitude	Drainage	Post (*55*)

Black walnut:			
Central States (prairie soils)		Surface soil depth Drainage Soil texture	Auten (*3*)
SE. Iowa		Depth A Total soil depth Mottling	Hansen & McComb (*35*)
SE. Iowa		Depth to claypan Soil color pH, Ca, K, N, Mg	Thomson & McComb (*61*)
S. Illinois	Slope position	Depth to mottling	Carmean (*15*)
Black locust:			
Central States (prairie soils)		Surface soil depth Drainage Soil texture	Auten (*3*)
Sweetgum:			
Delaware & Maryland (coastal plain)		Subsoil texture Depth to subsoil	Phillips (*53*)
S. New Jersey		Profile texture Subsoil thickness	Phillips & Markley (*54*)
Mississippi Valley	Slope position	Texture Internal drainage Depth to hardpan K content	Broadfoot & Krinard (*12*)

(continued)

Table 3.—Soil-site studies for other upland hardwoods in the East (continued)

Species and area	Topographic features	Soil features	Reference
Green ash:			
SE. Iowa	Slope position Aspect	Total soil depth Depth to imperious subsoil Past land use, erosion Soil color	Hansen & McComb (*35*)
Cottonwood:			
Mississippi Valley	Slope position	Texture Internal drainage	Broadfoot (*8*)
Willow oak:			
Mississippi Valley & (coastal plain)	Slope position	Texture K content	Beaufait (*5*)
Mississippi Valley & (coastal plain)	Slope position	Texture Depth to mottling or pan	Broadfoot (*11*)
Cherrybark oak:			
Mississippi Valley & coastal plain	Slope position	Surface soil depth Depth to mottling or pan Texture Internal drainage	Broadfoot (*9*)
Water oak:			
Mississippi Valley & Coastal Plain	Slope position	Surface soil depth Depth to mottling or pan Texture Exchangeable Na	Broadfoot (*10*)

Initial emphasis was placed on the southern pines, but now considerable soil-site information is also available for various eastern hardwoods (tables 2 and 3). Most of these studies are based on multiple-regression analysis of site index or of tree height (and tree age) measurements, and associated soil, climatic, and topographic factors. Significant site features pinpointed by these multiple regressions were used to calculate site-prediction tables for the field estimation of site quality. Site-prediction tables developed for a particular area provide a universal means for estimating site quality of all forest lands regardless of the composition or condition of existing vegetal cover. And species-comparison studies enable us to extend these site estimates to other tree species that might be considered for forest management.

Site evaluation based upon soil-site studies permits us to evaluate site only for the local spot in the landscape where we may happen to measure the significant features of soil, topography, or climate. Thus site evaluation still is a point observation comparable to point observations of site index using trees themselves. Still to be resolved is the problem of abstracting these point observations into an area classification of the landscape.

Effective land classification requires the use of aerial photographs and all available information about local soil and topography. Here is where forest managers can best use the skill and knowledge possessed by soil surveyors. Closer future coordination between soil-site research and soil survey can provide land-classification knowledge and techniques useful in forest-land management. Research can pinpoint the features of soil and topography important in classifying forest-land productivity. And soil surveyors can then incorporate this knowledge into soil surveys so as to obtain more useful inventories of forest lands.

Site-prediction tables developed from soil-site studies are applicable only to the particular area studied and, further, to the particular soil and topographic conditions measured within the study area. For example, results obtained for upland oaks in Ohio should not be applied in other states where soil, topography, and climate are different. Likewise, within a particular study area, results for upland soils should not be applied to bottomland soils or to other soil conditions not

included in the original site study. Soil conditions of heavily grazed woodlots or of cultivated or abandoned agricultural fields are also different from undisturbed forest soils where most hardwood-site studies are made. Accordingly, soil-site correlations developed from studies of undisturbed forest soils may not be applicable for hardwoods on soils disturbed by agriculture or heavy grazing. For example, foresters who have planted hardwoods in the Central States recognize that site conditions for hardwoods on abandoned fields are different from site conditions in nearby forest stands having undisturbed, but otherwise similar soils.[2]

The large number of soil-site studies listed in tables 2 and 3 appear impressive at first glance. However, we should bear in mind that eastern hardwoods cover a very large area that is extremely diverse in climate, topography, geology, and soil. Furthermore, eastern hardwoods include a large number of tree species that frequently respond in different ways to varying conditions of climate, soil, and topography. Accordingly, it soon becomes apparent that large gaps in our knowledge exist for many forest areas and for many important eastern hardwood species. For example, the northern Appalachian Mountains, the Lake States, and the glaciated portions of the Midwest have received relatively little study. Almost no site information is available for our more valued hardwoods such as black walnut, black cherry, yellow birch, basswood, and white ash.

A review of the many soil-site studies for eastern hardwoods (tables 2 and 3) reveals some general trends about the soil and topographic features frequently associated with site-quality changes. All species of trees apparently respond to favorable site conditions even though the amount of response varies and even though certain tree species are more tolerant than others of unfavorable site conditions. Accordingly, the features found to be closely related to site quality for hardwoods are usually the same soil, topographic, and climate features important for coniferous growth.

Soil conditons most important are generally those that express soil depth, soil texture and stone content, and soil

[2]Carmean, W. H., F. B. Clark, and P. R. Hannah. *Forest trees on abandoned land improve soil conditions and subsequent growth of planted hardwoods.* Unpublished manuscript submitted to Soil Sci. Soc. Amer. Proc. 1969.

drainage—that is, those soil properties " . . .which influence the quality and quantity of growing space for tree roots" (*18*). In general, site quality increases as soil depth increases: trees seem to be particularly affected by depth changes in the surface-soil layers where the majority of tree roots are concentrated. Usually medium-textured soils are the best sites, and site quality decreases for both coarse-textured soils and for fine-textured soils. Site usually decreases as stone content increases, and sometimes as drainage becomes poorer.

Topographic conditions most important are slope position, aspect, slope steepness, slope shape, elevation, and latitude. The best sites usually are found on lower slopes, north and east aspects, and on gentle, concave-shaped slopes. Poorer sites usually are found on narrow ridges and upper slopes, on south and west aspects, and on steep convex-shaped slopes. Obviously, topography can have no direct effect on tree growth; it is, however, closely related to differences in microclimate, soil moisture, and soil development. Accordingly, topography generally serves as an index of materials and conditions required for good tree growth—moisture, nutrients, temperature, and so on.

Even though we can generalize about soil and topographic features related to good tree growth, we find that soil-site studies show considerable variation in site features found to be important. Features important in one area may be unimportant in another. A feature may even show positive trends in one area and a negative correlation with site quality in another area.

One reason for differing results is that tree species vary in their response to differences in soil and topography. This is natural, and we should expect upland oaks to respond differently than black walnut, or than sweetgum or willow oak growing on bottomland alluvial soils. Another reason for differing results is due to differences in study areas. Topography would obviously be far more important in a rough hilly or mountainous area than in areas having flat or rolling topography. Drainage or soil texture would be unimportant in areas where all the soils are well drained and where soils are similar in texture. And areas having coarse-textured soils would usually show increases in site index as the content of silt and clay increased, while in contrast, areas having mostly fine-textured soils usually show decreases in site as texture becomes heavier.

An additional reason for differing results is related to the methods used in statistical analysis. Multiple-regression equations contain those soil and topographic variables that in combination give the most precise estimates of site quality. These equations have much practical value as they can be used to closely estimate site quality by using relatively few features of soil and topography. However, care must be exercised in interpreting the effects of significantly important factors and of those not significant in the regression analyses. Multiple-regression equations usually list site features in the order of their significance—that is, those features closely associated with large changes in site quality are listed first, and factors of less significance in the analysis appear in a secondary position. Thus, the trends expressed for the highly significant site features are very dependable while, in contrast, the trends expressed for the less significant variables often are conditioned by the effects of the stronger variables. This may be particularly true when considerable correlation occurs among the various site features listed in the equation.

Furthermore, we should recognize that many soil and topographic features may be associated with site quality in addition to those that appear in the final regression equation. The many simple correlations between site quality and various individual soil and topographic features are usually evident from scatter diagrams, or from computer screenings used as the first step in regression analyses. However, later regression computations may result in the dropping of many factors that show initial trends—because (1) they are closely correlated to other more significant factors that are retained in the equation, and (2) their retention would not materially improve the accuracy in predicting site quality by the regression equation.

Even though initially promising factors may be dropped during regression analysis, their influence may still be indirectly retained in the final equation. For example, both slope position and soil depth may be closely associated with site quality. However, these two features may also be closely related to each other—that is, deep soils occur on lower slopes and shallow soils on upper slopes. Therefore, a regression equation containing only slope position might adequately express both (1) the moisture and microclimate effects of slope position and (2)

indirectly the effects of soil-depth differences that are closely associated with slope position.

Site quality is related to the natural occurrence of hardwood species, as well as to their growth and yield. Certain hardwoods such as upland oaks commonly grow on almost all upland soils and over almost the entire range of site quality. For example, stem-analysis data showed that site index for black oak in southeastern Ohio ranged from a low of 34 feet to a high of 106 feet (*17*). Similar wide ranges in site index were observed for various upland oaks in the Southern Appalachians, in the Blue Ridge Mountains, and in the Virginia-Carolina Piedmont (*40*). In contrast, other hardwood species are much more limited in their occurrence and may be restricted to certain soils or to relatively narrow ranges of site quality. Hardwoods often restricted to the poorer sites include post, blackjack, and chestnut oaks. Hardwoods often restricted to medium and good sites include those valued for furniture and veneer such as yellow-poplar, black walnut, white ash, basswood, and sugar maple.

CONCLUSIONS

Both the quantity and quality of yield for eastern hardwoods vary greatly with site quality. Many hardwoods, such as upland oaks, commonly occur over a wide range of sites while, in contrast, other hardwood species may occur on a relatively narrow range of good or poor site. Generally site is associated with those soil features that determine the quantity and quality of growing space for tree roots. Topographic conditions are important because topography is an index of microclimate and soil conditions required for good tree growth.

Many methods for evaluating site quality for hardwoods exist, but the direct measurement of site index from standing trees is the most dependable—that is, if suitable trees and accurate site-index curves are available. The three indirect methods of estimating site quality are based on plant indicators, soil types, and results from soil-site research. All direct and indirect approaches to site evaluation are useful, and all of these methods are in reality complementary rather than contradictory. Accordingly, the future should show not a segregation into strict lines of soil, ecological, or mensurational disciplines, but a spirit of tolerance, respect, and constructive borrowing and learning from all fields of site evaluation.

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GENETICS AND TREE IMPROVEMENT IN THE OAK—YELLOW-POPLAR TYPE

by CHARLES D. WEBB, *plant geneticist, Forestry Sciences Laboratory, Southeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Athens, Georgia.*

MY DISCUSSION of tree improvement is based upon the realization that genetic tree improvement, as accomplished by selection and breeding, must be combined with intensive silviculture so that trees of the desired quality level can be produced economically. Superior strains of hardwoods must be planted on carefully selected and well-prepared sites, and planting probably should be followed by some form of weed control and fertilization. Also, natural regeneration from sprouts can be relied upon after many hardwood logging operations. Therefore, hardwood planting programs should be restricted to those situations where natural regeneration is either from undesirable species, is inadequate, or is completely lacking.

In this context, I will discuss what we know about genetic variation within the species of the oak–yellow-poplar type, and how much improvement we can expect from selection, breeding, and intensive silviculture. I will concentrate on only a few of the most important species: the oaks, yellow-poplar, black walnut, and sweetgum. Because our knowledge of inheritance within any one species is incomplete, occasional references to other species will fill in gaps in our knowledge.

An important qualification is necessary: most of the results I will discuss are based on trees less than 10 years old. Therefore, the inheritance figures must be considered tentative. Unfortunately, many of the studies established over 10 years ago have suffered from poor survival and site variability.

GENETIC VARIATION WITHIN SPECIES

Geographic Seed Sources

Genetic variation within a species can be separated into differences among geographic seed sources or races, and among individual trees within seed sources. Excepting a few oaks, all the species we are considering have wide geographic distribution: sweetgum grows naturally in 23 states, yellow-poplar in 26, black walnut in 31, and northern red oak in 29 *(U.S. Dep. Agr. 1965).* These areas include wide ranges of latitude, longitude, and elevation. Against such a diverse environmental background, natural selection has produced racial variation that is economically significant.

The most important and consistent differences among geographic seed sources in hardwoods have appeared in dormancy relationships. The dormancy relationships determine when seedlings from a particular seed source will begin growth in the spring and when they will stop growing in the fall. Upon this depends (1) whether seedlings of a particular source suffer any frost damage, and (2) how efficiently they use the growing season available to them. Racial differences in dormancy are known to exist in yellow-poplar *(Farmer et al. 1967, Sluder 1960, Funk 1958),* northern red oak *(Kriebel 1965),* black walnut *(Wright 1954),* sweetgum[1], sugar maple *(Kriebel 1957),* and *Populus (Pauley and Perry 1954).* Definite differences in frost damage have been reported in yellow-poplar *(Funk 1958),* shumard oak *(Gabriel 1958),* sugar maple *(Kriebel 1957),* and ash *(Santamour 1963).* A general rule has been stated *(Pauley and Perry 1954):*

> In general, movement from the latitude of the natural habitat northward (i.e. with longer days) prolongs the active period of growth; and movement southward (i.e. with shorter days) shortens it. Such modifications on the length of the active growth period normally result in marked differences in seasonal increment and frost hardiness. Thus, movement of plants into a day-length regime longer than that of the native habitat characteristically gives increased height growth accompanied by decreased

[1]Roberds, James Hall. *Patterns of variation in several characteristics of sweetgum (Liquidambar styraciflua L.) in North Carolina.* Unpublished M.S. thesis, N. C. State Univ. School of Forestry, 1965.

resistance to autumnal frosts; whereas movement into a short-day regime results in dwarfing, associated with increased frost resistance.

Few studies are old enough to permit comparisons of total volumes per acre of different seed sources, but significant differences in early height growth have been reported for several species: yellow-poplar *(Farmer et al. 1967, Thor*[2]*)*, northern red oak *(Kriebel 1965)*, shumard oak *(Gabriel 1958)*, black walnut *(Wright 1954)*, sugar maple *(Kriebel 1963)*, and sycamore *(Fogg 1966)*. A few studies have failed to show significant differences, even among seedlings from sources that are widely separated *(Sluder 1960, Santamour and Schreiner 1961, Schreiner and Santamour 1961, Roberds*[1]*)*.

Racial variation has appeared in other important traits: epicormic sprouting of a European species of oak *(Irgens-Moller 1955)*, apical dominance, forking, and drought tolerance in sugar maple *(Kriebel 1957)*, and cork on seedlings of sweetgum (*Roberds*[1]).

None of the seed-source studies has shown a single, widely adapted source for any of the species studied. The local source has not always produced the best growth. But local sources have been in phase with their environment—they have been frost-resistant to an acceptable degree, and they have efficiently used the growing season available to them. When growth and form are considered, there are notable instances where distant seed sources and individual trees perform exceptionally well. Because these exceptions are encountered in both conifers and hardwoods, a combination of racial, stand, and individual tree selection is recommended for maximum gain in tree-improvement *(Wright 1967)*. Studies should maintain the identity of both family and racial relationships. Results on growth and yield should be considered tentative until the tests have endured some severe years, including hard winters, early and late frosts, hot summers, drought, disease epidemics, and insect outbreaks.

[2]Personal communication with Dr. Eyvind Thor, Associate Professor, Department of Forestry, University of Tennessee, Knoxville.

Individual Tree Variation

The maximum genetic gain will often be achieved by selecting the best families from certain races and the best individuals from certain families. The success of this approach will depend upon the existence of a wide range of hereditary variation among individual trees. There are conspicuous gaps in our knowledge of inheritance within the species under consideration. Many of these gaps should be filled when the many well-designed studies that have been installed recently are analyzed. But even with the limited knowledge available, it is possible now to come up with some idea of the success we can expect from selection for the different traits.

Our knowledge of inheritance within these species is summarized in table 1. The data come from reports by Wilcox *(1968)* on sweetgum, Taft[3] on yellow-poplar, Kriebel *(1965)* on northern red oak, and Wilcox and Farmer *(1967)* and Schreiner *(1959)* on *Populus.* The data on sycamore and disease resistance of yellow-poplar clones come from our work at Athens, Georgia. The table shows only the approximate degree of hereditary control. Heritability fractions, although simple in concept, are difficult to estimate precisely. Stated generally, heritability is the fraction of the total variation (genetic and environmental) that is controlled by heredity and is available for selection and breeding. The higher the heritability, the easier it is to make progress through selection and breeding.

The most important conclusion to be drawn from this summary is: there is significant and usable genetic variation among individual trees for almost every trait of interest. Genetic control of dormancy relationships is consistently high; and that of branching, crown form, and bole straightness is intermediate. However, genetic control of height and diameter growth is within the low to intermediate range. Clones of *Populus* show very strong differences in resistance to certain diseases; similar differences in pest resistance can be expected in other species. Figures are not available on hereditary control of grain patterns or epicormic branching for these species, but undoubtedly genetic differences in these important traits will appear as trees

[3]Taft, Kingsley Arter, Jr. *An investigation of the genetics of seedling characteristics of yellow-poplar (Liriodendron tulipifera L.) by means of a diallel crossing scheme.* Unpublished Ph.D. thesis, N. C. State Univ. School of Forestry, 1966.

Table 1.–Relative degree of hereditary control of some economically important traits in several hardwood species

Characteristic	Species				
	Sweetgum	Yellow-poplar	Northern red oak	Sycamore	*Populus* spp. (clones)
Height	L-I[a]	sig.[b]	sig.	VL	I
Diameter	L	–[c]	–	L	I
Branching	I-H	–	–	–	sig.
Crown form	I	–	–	–	–
Straightness	sig.	–	–	–	sig.
Date of bud break	VH	–	–	sig.	VH
Date of leaf-fall or growth cessation	–	sig.	sig.	–	VH
Disease resistance	–	sig.	–	–	VH

[a]Degree of hereditary control:
VL - very low (h^2 = 0–.2)
L - low (h^2 = .2–.4)
I - intermediate (h^2 = .4–.6)
H - high (h^2 = .6–.8)
VH - very high (h^2 = .8–1.0)

[b]"Sig." indicates that family differences were significant but no heritability fraction was calculated.

[c]Dash indicates no report available.

in the progeny tests become older.

When these plantations are older and more complete analyses are available, it will be possible to combine the genetic information with data on the relative economic importance of each trait. This will provide a criterion for deciding which traits to improve and how to proceed most efficiently.

EXPECTED PROGRESS

Even in the face of incomplete knowledge on inheritance, numerous programs of applied tree improvement and genetics research are under way in almost every state east of the Mississippi for one or more species of the oak–yellow-poplar type. These programs are supported by private industries, universities, state forestry organizations, TVA, and the U.S.D.A. Forest Service. A complete summary of these programs would require a lengthy report. However, Dorman *(1966)* has summarized both pine and hardwood tree-improvement activities in the South and Southeast. Reports of some of the work under way in the Northeast are found in the proceedings of the 15th Annual Northeastern Forest Tree Improvement Conference.

How much progress can we expect from the action programs for tree improvement that are under way now in the hardwoods? How much can log quality be improved and rotations be shortened? Only highly speculative answers are possible now.

Those action programs that began with restrictive systems for selecting only the best-formed trees from natural stands will probably make appreciable improvements in straightness and self-pruning during the first generation of selection (fig. 1). Early progeny-test results on branching characteristics and straightness attest to this.

How much genetic improvement will be achieved in growth rate will remain a moot question for some time. Because of the highly variable nature of hardwood stands, it is impossible to use refined systems for comparing the growth of candidate trees with growth of their neighbors in the stand. (Yellow-poplar may prove to be an exception.) Consequently, the maximum gains in volume will have to wait until progenies are established in evenly spaced and well-attended plantations. Within these plantations, it will be possible to compare the growth of

Figure 1.—First generation selection will probably achieve substantial improvements in branching, which is related to self-pruning. While the tree shown on the left is not perfect, it exhibits much better self-pruning than the tree on the right.

outstanding individuals with that of their neighbors and with the rest of their family. Our early progeny test results on height and diameter indicate that this will be an effective and necessary procedure for achieving substantial improvements in growth rate.

The consensus is that rotations for high-quality veneer-log production might be shortened in some cases to as low as 30 or 40 years. This shortened rotation will be achieved by growing genetically improved stock on the best sites at wide spacings and by using fertilization, weed control, and possibly pruning.

The gains that the pulp industries will realize from hardwood tree improvement will depend on the acreages planted to hardwoods, and on the type of hardwood pulp required. At present, the pulp industries anticipate only limited hardwood planting because of the expense of artificially regenerating hardwoods and the abundance of natural regeneration from sprouts. This attitude may change as improved hardwood seedlings become available and as we learn more about growing hardwoods.

Some of the hardwoods, however, are capable of producing large volumes of pulpwood on certain sites. For example, our 7-year-old sycamore plantation of unimproved, nursery-run seedlings on a riverbottom old-field site south of Athens, Georgia, has produced an average of 2.06 tons of dry wood per acre per year on unfertilized plots. Plots that received a single application of 150 pounds of nitrogen per acre during the first growing season have averaged 2.29 tons of dry wood per acre per year, and those that received 300 pounds of nitrogen per acre averaged 2.42 tons per acre per year. These yields are comparable to yields reported for certain outstanding families of loblolly pine in the North Carolina State – Industry Cooperative Tree Improvement Program *(1968)*.

We plan to select and propagate the largest and best-formed trees from this sycamore plantation. If the largest trees (upper 10 percent) are put in a clonal seed orchard, gains in individual tree volume should approach 10 percent. However, if these trees are propagated by cuttings, there should be an increase in individual tree volume of about 20 percent. If we speculate further about the application of fertilizers to these selected cuttings, yields could approach 40 to 50 percent greater than those of unimproved, unfertilized stock.

A different type of hardwood pulp will be produced by the proposed silage sycamore concept *(McAlpine et al. 1966).* This controversial concept would combine very short rotations, mechanical harvesting, and repeated coppice regeneration. The proposal has great promise for producing large volumes of certain types of hardwood pulp, and genetically improved strains will play an important part in the success of the concept.

CONCLUSION

Our expanding knowledge of inheritance in forest trees —hardwoods and conifers—shows that we have available a large supply of genetic variation in growth rate, tree quality, and pest resistance. I am confident that careful selection and breeding, when combined with good silviculture, will be effective in economically producing high-quality veneer logs and high volumes of pulpwood.

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DIAMETER GROWTH

of individual hardwood trees

The effect of certain tree and environmental factors on the growth of several species

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RICHARD D. LANE, DIRECTOR

THE AUTHOR

GEORGE R. TRIMBLE, JR., research forester, attended the University of Idaho and the University of Maine, where he received his bachelor's degree in forestry, and has also done graduate work at Duke University in forest soils. He joined the U. S. Forest Service in 1932 and the Northeastern Forest Experiment Station in 1939. He has served in flood-control surveys and has done research on management of northern hardwoods in New Hampshire. He now is project leader in timber-management research, stationed at the Station's Timber and Watershed Laboratory at Parsons, W. Va.

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Introduction

BETWEEN 1959 and 1967 a study of d.b.h. growth rates was made on individual hardwood trees near Parsons, W. Va. From this study, we obtained information that will help foresters to predict growth. We learned that the correlation of the more easily used crown classification with d.b.h. growth is as good as or better than the correlation of vigor classes with d.b.h. growth. We discovered that when crown classes are identified, crown measurements such as width and length add practically nothing of predictive value. We established that tree d.b.h. is positively and strongly correlated with d.b.h. growth in these mixed hardwood stands. We learned that a measure of total surrounding basal area is not a good predictor of individual tree d.b.h. growth in these stands. We compiled annual d.b.h. growth by crown classes for several important species on several levels of forest site quality.

In this report, d.b.h. growth is discussed in relationship to: (1) crown and vigor classes, (2) crown measurements, (3)

initial d.b.h., (4) basal-area density, and (5) species and site quality.

The Study Area

The study locale, the Fernow Experimental Forest, which lies at an elevation between 1,800 and 3,600 feet, has an annual precipitation of 58 inches and an annual average temperature of 48° F. The average land gradient is about 35 percent. The soil mantle is 3 to 4 feet deep, medium textured, and well drained.

The trees were growing in mixed hardwood stands where average stand densities ranged, when the study was initiated, from 60 to 120 square feet of basal area in trees over 1.0 inch d.b.h. Site indexes (for oak) were: 85 (an excellent site), 63 (a fair site), and, for some white (*Quercus alba* L.) and chestnut oak (*Q. prinus* L.), 50 (a poor site). The stands, approximately 55 years old in 1959, were even-aged with a scattering of older dominant residuals. The stands on the two better-site areas had been partially cut—a combination thinning and improvement cutting—in 1954. The poor-site stands had never been cut.

Methods

Sample trees were selected mechanically: the timber cruiser designated each fifth tree he measured in the stand inventory as a sample.

The following measurements and observations were taken on these trees: (1) d.b.h. (at 4.5 feet as measured and indicated by a scribe mark); (2) total tree height, measured with a Spiegel Relaskop; (3) crown length, from the lowest live branch to the top of crown, measured with a Spiegel Relaskop; (4) crown width, measured on the ground as an average of the north-south and east-west crown projection; (5) basal area around the sample tree, measured with a Spiegel Relaskop, using 10 and 40 factors; (6) crown class; and (7) vigor class.

Measurements were repeated after four and eight growing seasons. About 1,000 trees were included in the study.

Growth Related to Crown and Vigor Classes

Two types of tree classes related to growth rate have been used by foresters to guide selective marking: crown classes and vigor classes (see definitions in appendix 1).

Tree vigor classes have been used successfully to predict d.b.h. growth rates for hardwood species *(3, 4)*. In the development of vigor classifications, emphasis has been placed on crown features such as position in the canopy, on size and relative "health," and on bark characteristics *(1, 2)*. Probably the least subjective judgment made in assigning vigor class is crown position; and the question naturally arises: Is vigor class actually better correlated with diameter growth than is crown position alone? If not, then why not rely on the simpler-to-use and better-recognized crown classifications described in almost all textbooks on silviculture, and discontinue making all the additional and highly subjective secondary observations?

This study provided the opportunity to test the two yardsticks, and the sample trees were classified by both systems. Nine sets of comparisons were made; they included six species and three site quality classes.

The rank correlation (R) shows the relative accuracy of the two systems in classifying tree d.b.h. growth rates. The rank correlation was computed for: (1) crown class and growth and (2) vigor class and growth (table 1). The system of classification with the larger value of R could be considered best.

The rank correlations showed that for five of the nine sets of data the separation into crown classes ranks the trees more accurately for growth rates than does separation into vigor classes, although differences are small. The highest R, for both crown and vigor classifications, was for site index 85 red oak, indicating excellent suitability of both as predictors of d.b.h. growth.

R for sugar maple was low, especially for crown class. The extreme shade tolerance of this species may account for this low accuracy of ranking by crown class. Crown position appears to

make less difference in growth rates with such species (although our information on this in the case of sugar maple is limited because sample trees were confined to the lower crown classes) because they can utilize lower intensities of light more efficiently. With them, we might reason that a vigor classification based mainly on the appearance of the crown—with little weight given to crown position—might be the best way to classify trees for growth-prediction purposes.

Overall, there appears to be little advantage to using either crown or vigor classes in choosing which trees to cut or leave in thinning operations in stands of middle-aged mixed hardwoods. We want to emphasize that the culls had been removed from these fairly-well-stocked to well-stocked stands. In open understocked stands or in highly defective or decadent stands, vigor class, in comparison to crown class, might show greater accuracy in ranking trees for growth prediction purposes.

An interesting trend showed up between crown class and the size of the coefficients of variation (table 2). The dominant crown class had the lowest average coefficient of variation—0.25; and the others fell in order with a rising c.v. as tree dominance class decreased. That is, the average c.v. for the codominant class was 0.28; for intermediate crown class, 0.39; and for overtopped, 0.50. This indicates that growth varied least within the dominant crown class and most within the overtopped class.

The degree of agreement between corresponding crown and vigor classes varied with species and tree classes themselves (table 3). For red, chestnut, and white oak the ratings by crown and vigor class corresponded quite well. Yellow-poplar classifications of crown class also agreed fairly well with the corresponding vigor class except for the codominant-vigor II comparison. With black cherry agreement was good for the two middle classes, and poor for the highest and lowest classes. Observers rated the vigor of the tolerant sugar maple relatively higher for its crown class than they did any of the other species. Growth for the lower crown classes of this species can be expected to be greater relative to the growth of the higher crown classes than for the less-tolerant species like yellow-poplar.

Growth Related to Crown Measurements

The effect of crown dimensions on diameter growth rates has long been recognized, and investigations have demonstrated direct relationships between radial increment and crown size. In this study we assessed the association between growth at breast height and these crown measurements: (1) crown length, (2) live crown ratio, (3) crown width, and (4) the product of crown length times crown diameter.

Correlation coefficients were computed for each species and site, ignoring crown class (table 4); and for each species and site, considering crown class. These were used to judge the degree of association between the various crown parameters and diameter growth.

When the growth data were not grouped by crown class, certain crown measurements were found to be important indicators of potential diameter growth. Nine groups of trees (species-site combinations) were tested with these results:

- Seven groups showed a significant effect of crown diameter on growth, with a maximum r^2 of 0.66.
- Eight groups showed a significant effect on growth of the product of crown length and crown width, with a maximum r^2 of 0.48.
- Five groups showed a significant [1] positive effect of crown length on d.b.h. growth, with a maximum r^2 of 0.29.
- No group showed a significant effect of crown ratio on d.b.h. growth.

When the growth data were grouped by crown class, significant relationships between growth and the other crown parameters were rarely found, indicating that these variables added but little additional information about diameter growth rates. In

[1] Significance is accepted at the 5-percent level.

only 11 out of a total of 124 sets of data were significant relationships indicated between crown measurements and d.b.h. growth. These are so few we can safely conclude that, if crown class is identified, the additional crown measurements are not very likely to be of appreciable value as growth predictors.

For practical classification of trees for growth prediction purposes in stands similar to these, identification of crown class alone, which is a simple observation, is preferable to any of the crown measurements tested; and once crown class is identified, none of these measurements would be very likely to explain additional d.b.h. growth variation.

Growth Related to Initial D.B.H.

Analyses showed that, on the average, the larger trees grew faster in diameter than the smaller trees. The reason for this is that the larger trees occupy more dominant positions in the canopy (and have more voluminous functional crowns); this is shown by the larger average d.b.h.'s for the more dominant crown classes (table 5). All of the nine species-site combinations tested showed significant positive correlations between d.b.h. growth and initial d.b.h. Red oak on site index 85 had the highest r^2—0.86; and chestnut oak on site index 50 had the lowest r^2—0.19. Because of this relationship between growth rate and d.b.h., tree diameter can be used to appraise relative tree growth rates in even-aged stands.

When analyses of the relationship between d.b.h. and d.b.h. growth were made on trees *within* crown class, only 4 out of the 21 groups of data tested showed significant correlations (table 5). This indicated that within crown classes tree d.b.h. was not a good predictor of diameter growth.

Growth Related to Basal-Area Density

Ten and 40 factors were used to measure basal-area density. The 10-factor measurements extend twice as far as the 40-factor measurements (table 6).

The data indicated a general—if not invariable—reduction in surrounding basal area with increasing tree dominance (table 7). In other words, dominant trees tended to reduce nearby competition—or to be dominant because of a lack of nearby competition. This was slightly more evident with the 40-factor measurements than with the 10-factor.

When trees were not grouped by crown classes, correlation between d.b.h. growth and surrounding basal area, taken with both 10 and 40 factors, were significant at the 5-percent level in only five out of nine species-site combinations (table 8). Moreover, even where significance was attained, correlation was weak, indicating that total surrounding basal area had little value as a predictor of d.b.h. growth rates of individual trees.

In six cases out of nine, the 40-factor (which has only half the reach of the 10-factor) was a slightly better predictor of growth, as indicated by the size of the r^2, than the 10-factor (table 8).

The next step was to study the effect of basal-area density (as expressed by the 40-factor) on growth *within* crown classes. In only 2 out of 15 groups tested were significant correlations found (table 9), indicating that within a crown class surrounding basal area is poorly correlated with d.b.h. growth.

The general weakness of total surrounding basal area as a predictor of diameter growth should not be suprising in stands like these comprising many species with different crown and diameter growth characteristics, different shade tolerances, and with a rather wide range of ages for even-aged stands. The competitive effects on a tree of surrounding stems depends on: (1) the relative sizes of the sample tree and its competitors, (2) the distance from sample tree to surrounding stems, and (3) interaction between relative tree size (sample trees vs. competitors)

and distance between stems. Use of basal area as a growth predictor could be expected to be much more appropriate in more even-aged stands composed of fewer species.

Growth by Species and Site Quality

Diameter growth data for a number of species were compiled by oak site-index class and tree-crown class (table 10). Annual d.b.h. growth was determined only for classes represented by five or more study trees. As a result, some of the cells are empty. However, coverage was sufficient to indicate clearly that growth was positively correlated with site quality and that an increase in crown dominance was accompanied by an increase in growth.

These findings confirmed the results of other studies made in the area. Moreover, the d.b.h. growth ranking, by species fell pretty much in line with the results of other studies made in similar 45- to 60-year-old stands *(5, 6)*. (We want to emphasize that these were middle-aged stands. In stands older or younger the relative d.b.h. growth rates of the species might be, and probably would be, considerably different.)

Because of the lack of data for many groups—that is, the absence or scarcity of study trees in many classifications—species growth comparisons were incomplete. However, some things stand out. Middle-aged red oak grew faster in diameter than any of its associates on site indexes 63 and 85. Yellow-poplar was a not-too-close second on the higher site. White and chestnut oak grew slowly. Sugar maple grew faster in subdominant positions on site index 85 than black cherry or yellow-poplar. This was to be expected of such a tolerant species.

Considering the great variability of d.b.h. growth rates and the low number of sample trees in some classes, too much reliance should not be placed on the accuracy of the averages; some classes were significantly different from others, many were not. The confidence limits (table 10) indicate which categories have overlapping growth rates and do not differ at the 5-percent level in d.b.h. growth rates.

Summary and Discussion

Comparison of the relationship of d.b.h. growth to crown class and vigor class showed no clearcut advantage of either as a predictor of d.b.h. growth rates. Both ranked growth in logical order. Because the standard crown classes are easier to use, we recommend them, rather than vigor classes, for use as growth predictors.

These crown variables were studied in their relationship to d.b.h. growth: crown length, crown ratio, crown diameter, and the product of crown length by crown diameter. When trees were not separated into crown classes but only into species-site groups, crown diameter and the product of crown length by crown diameter were significantly correlated with d.b.h. growth for most species-site combinations. For about half of the combinations, crown length was correlated with d.b.h. growth. Crown ratio was correlated with growth in none of the nine combinations. When trees were grouped by crown class within a species-site combination, we found little relationship of any of these crown variables to d.b.h. growth. For purposes of predicting d.b.h. growth, these variables add but little to crown class alone.

Trees of greater d.b.h. grew faster; initial d.b.h. of hardwood trees was strongly and positively correlated with subsequent 8-year d.b.h. growth for a number of species-site combinations. However, when the combinations were stratified by crown class, few groups showed significant relationships between initial d.b.h. and d.b.h. growth. This indicated that the real growth relationship was to crown class; larger diameter trees in the even-aged stands had more dominant crowns and for this reason grew faster.

Averages of total basal area taken around study trees indicated there was a general reduction of tree-dominance class with greater surrounding basal-area density. When trees were not stratified into crown classes, d.b.h. growth was significantly correlated with surrounding density in five out of nine species-site groups. However, in the five cases correlation was weak, indicating that total

surrounding basal area had little value as a predictor of d.b.h. growth rates for individual trees. Moreover, when the study trees were further stratified by crown classes within the species-site combinations, basal-area density showed little relationship to growth.

This study indicated that a strong relationship existed between d.b.h. growth and species, site quality, and crown class. Although the d.b.h. growth for combinations of these factors was highly variable, measurements of initial d.b.h., surrounding basal area, and several crown parameters added little significant growth-prediction information.

For operations involving tree-growth assessment, such as selective marking and determining rotation diameters, this study indicated that in stands like these, the best growth predictors—within a species on a given site—are crown class and relative d.b.h. Because of the heterogeneous nature of the stands—mixtures of species and tree size—undifferentiated basal-area measurements are not good predictors of growth. Crown class (which expresses the vigor of the tree's food-manufacturing process) and relative d.b.h. (which reflects the efficiency of the crown) are highly correlated, and both reflect to an extent the total competitive pressure of surrounding stand density.

In young even-aged stands composed of only a few species of similar growth characteristics, relative d.b.h. is probably the most easily assessed indicator of growth capacity; crown classes are hard to distinguish in such stands. Crown class, as an indicator of growth, becomes more usable in older stands, in stands composed of a greater variety of species, and in stands encompassing a wider age span. In other words, in uniform stands d.b.h. is the best practical indicator of growth potential; in diversified stands crown class is a better yardstick.

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Appendix I

VIGOR CLASS DEFINITIONS*

Vigor I.—A tree in this vigor class has a large, healthy, full crown in a dominant or codominant position. Half the crown or more is exposed to direct sunlight. The crown is dense, with no evidence of disease or injury. Crown quality and position is more important than total length. The bark and twigs have good color and vigorous appearance.

Vigor II.—A tree in this vigor class has a fair-sized crown in a codominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and not so perfect as that of a Vigor I tree. This class may also include a large-crowned tree that fails to meet the requirements of Vigor I because of mechanical injury or dying limbs.

Vigor III.—A tree in this vigor class has a medium to small crown usually in an intermediate position. Only the tip is exposed to direct sunlight. The crown may be open, with some dead or broken limbs, or thinly foliated. This class also includes trees with fair to large crowns in a codominant position that cannot meet the requirements for a Vigor I tree.

Vigor IV.—A tree in this class usually has a small crown in an overtopped position. This class includes all living trees that fail to meet the requirements of higher vigor classes.

CROWN CLASS DEFINITIONS

Dominant.—Trees with crowns extending above the general level of crown cover and receiving full light from above and partly from the sides; larger than the average trees in the stand, and with crowns well developed but possibly somewhat crowded on the side.

Codominant.—Trees with crowns forming the general level of the crown cover and receiving full light from above but comparatively little from the sides; usually with medium-sized crowns more or less crowded on the sides.

Intermediate.—Trees shorter than those in the two preceding classes but with crowns extending into the crown cover formed by codominant and dominant trees; receiving a little direct light from above but none from the sides; usually with small crowns considerably crowded on the sides.

Overtopped.—Trees with crowns entirely below the general level of the crown cover, receiving no direct light either from above or the sides.

*Bark characteristics were used only very incidentally. These vary greatly by species and for some species appear to vary little or not at all with tree vigor. Moreover, they have proved applicable very inconsistently across site qualities.

Table 1.—*Rank correlations between d.b.h. growth rates and crown and vigor classes*

Species	Oak site index	Rank correlation	
		Crown class	Vigor class
	Feet	*R*[1]	*R*
Red oak (*Quercus rubra* L.)	85	0.80	0.75
Red oak	63	.67	.71
White oak	63	.50	.44
Yellow-poplar (*Liridodendron tulipifera* L.)	85	.54	.52
Sugar maple (*Acer saccharum Marsh.*)	85	.31	.49
Black cherry (*Prunus serotina* Ehrh.)	85	.53	.66
Chestnut oak	63	.58	.57
Chestnut oak	50	.46	.55
White oak	50	.65	.58

[1] All of the R's are significant at the 5-percent level.

Table 2.—*Comparison of coefficients of variation of 8-year d.b.h. growth rates by crown class and vigor class*

Species and oak site index	Dominant crown classs	Vigor class I	Codominant crown class	Vigor class II	Intermediate crown class	Vigor class III	Overtopped crown class	Vigor class IV
Red oak: site index 85:								
8-year d.b.h. growth	3.01	2.93	2.23	2.06	1.39	1.30	0.64	0.55
Coefficient of variation	.14	.14	.28	.32	.40	.53	.65	.49
Number of trees	7	11	30	27	18	23	13	7
Yellow-poplar: site index 85:								
8-year d.b.h. growth	1.68	1.64	1.39	1.21	0.95	1.00	—	—
Coefficient of variation	.26	.26	.30	.33	.35	.40	—	—
Number of trees	18	27	22	15	9	6	—	—
Black cherry: site index 85:								
8-year d.b.h. growth	1.18	1.46	1.22	1.21	0.78	0.75	0.47	0.45
Coefficient of variation	.30	.24	.32	.33	.55	.53	.46	.39
Number of trees	11	11	42	39	21	25	7	6
Sugar maple: site index 85:								
8-year d.b.h. growth	—	—	—	1.28	1.31	0.73	1.00	0.70
Coefficient of variation	—	—	—	.43	.33	.42	.55	.71
Number of trees	—	—	—	35	14	14	40	7
Red oak: site index 63:								
8-year d.b.h. growth	2.10	2.29	1.98	1.99	1.36	1.49	1.04	0.97
Coefficient of variation	.17	.19	.24	.20	.34	.28	.23	.27
Number of trees	5	7	32	23	14	21	7	7

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Table 2.—Continued

Species and oak site index	Dominant crown class	Vigor class I	Codominant crown class	Vigor class II	Intermediate crown class	Vigor class III	Overtopped crown class	Vigor class IV
White oak: site index 63:								
8-year d.b.h. growth	1.50	1.45	1.24	1.28	1.03	1.09	0.52	0.72
Coefficient of variation	.24	.27	.36	.29	.50	.54	.65	.72
Number of trees	5	4	14	12	8	9	4	6
Chestnut oak: site index 63:								
8-year d.b.h. growth	1.48	1.49	1.16	1.21	0.87	0.90	0.53	0.51
Coefficient of variation	.37	.36	.26	.28	.41	.40	.53	.54
Number of trees	22	15	80	75	30	45	19	16
Chestnut oak: site index 50:								
8-year d.b.h. growth	—	—	0.66	0.73	0.59	0.59	0.48	0.48
Coefficient of variation	—	—	.17	.10	.19	.19	.23	.23
Number of trees	—	—	5	3	15	15	6	6
White oak: site index 50:								
8-year d.b.h. growth	—	—	0.57	0.55	0.45	0.44	0.19	0.21
Coefficient of variation	—	—	.30	.34	.43	.45	.71	.74
Number of trees	—	—	12	10	25	25	15	15

Table 3.—*Deviation of vigor classification from crown class*

[Number of sample trees is shown in parentheses]

Species	Site index (oak)	Percentage division of trees in a crown class by vigor classes											
		Dominant crown class			Codominant crown class			Intermediate crown class			Overtopped crown class		
		Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III	Vigor II	Vigor III	Vigor IV	Vigor II	Vigor III	Vigor IV
Red oak	85	100	0	0	13	67	20	33	61	6	8	46	46
		(7)			(4)	(20)	(6)	(6)	(11)	(1)	(1)	(6)	(6)
Red oak	63	100	0	0	6	75	16	0	86	14	0	29	71
		(5)			(2)	(24)	(5)[a]		(12)	(2)		(2)	(5)
White oak	63	80	20	0	0	79	21	0	62	38	0	25	75
		(4)	(1)			(11)	(3)		(5)	(3)		(1)	(3)
Yellow-poplar	85	89	11	0	50	50	0	33	67	0	0	0	100
		(16)	(2)		(11)	(11)		(3)	(6)				(3)
Black cherry	85	55	45	0	12	74	14	10	76	14	0	57	43
		(6)	(5)		(5)	(31)	(6)	(2)	(16)	(3)		(4)	(3)
Sugar maple	85	0	0	0	67	33	0	79	14	0	60	28	12
					(2)	(1)		(11)[b]	(2)		(24)	(11)	(5)
Chestnut oak	63	64	32	4	1	84	15	3	90	7	0	26	74
		(14)	(7)	(1)	(1)	(67)	(12)	(1)	(27)	(2)		(5)	(14)
Chestnut oak	50	—	—	—	40	60	0	0	100	0	0	0	100
					(2)	(3)			(15)				(6)
White oak	50	—	—	—	17	83	0	0	96	4	0	7	93
					(2)	(10)			(24)	(1)		(1)	(14)

[a] 1 tree—3 percent in vigor class IV.
[b] 1 tree—7 percent in vigor class I.

Table 4.—*Correlation of d.b.h. growth with crown features (ignoring crown class)*

Species and site index	Number of trees	r^2 — Coefficient of variation			
		With crown length	With crown ratio	With crown diameter	With product of crown length x crown diameter
Red oak: site index 85	55	0.07*	0.04^N	0.66**	0.48**
Red oak: site index 63	58	.03^N	.05^N	.25**	.21**
White oak: site index 63	31	.06^N	.004^N	.08^N	.07^N
White oak: site index 50	52	.08*	.02^N	.27**	.23**
Chestnut oak: site index 63	130	.04*	.005^N	.14**	.08**
Chestnut oak: site index 50	26	.29**	.14^N	.06^N	.28**
Sugar maple: site index 85	57	.03^N	.01^N	.08*	.08*
Yellow-poplar: site index 85	51	.12*	.01^N	.28**	.28**
Black cherry: site index 85	81	.02^N	.001^N	.30**	.24**

* r is significant at the 5-percent level.
** r is significant at the 1-percent level.
^{N} r is not significant at the 5-percent level.

Table 5.—*Correlation between d.b.h. growth and initial d.b.h.*

Species and crown class	Site index (oak)	Stems	Average d.b.h. 1959	Range in d.b.h. of sample trees 1959	r^2 between d.b.h. growth and initial d.b.h.[1]
		No.	*Inches*	*Inches*	
Red oak	85	68	11.7	6.3-20.0	0.86**
Dominant		7	16.9	11.0-20.0	—
Codominant		30	13.7	8.6-17.9	.42**
Intermediate		18	9.5	6.3-13.6	.02^N
Overtopped		13	7.2	6.3- 9.4	.05^N
Yellow-poplar	85	53	14.1	5.8-21.7	.66**
Dominant		18	17.8	10.6-21.7	.06^N
Codominant		22	14.4	9.0-16.8	.00^N
Intermediate		9	9.3	7.6-16.7	—
Overtopped		4	6.2	5.8- 6.5	—
Sugar maple	85	57	6.9	5.0-11.9	.49**
Dominant		—	—	—	—
Codominant		3	10.3	7.7-11.9	—
Intermediate		14	8.0	5.1-16.1	.02^N
Overtopped		40	6.3	5.0-12.1	.02^N

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able 5.—Continued

Species and crown class	Site index (oak)	Stems	Average d.b.h. 1959	Range in d.b.h. sample trees 1959	r^2 between d.b.h. growth and initial d.b.h.[1]
Black cherry	85	81	12.6	6.8-20.1	.43**
Dominant		11	15.6	11.7-20.1	.01^N
Codominant		42	14.0	11.0-21.8	.13*
Intermediate		21	9.9	7.7-11.3	.01^N
Overtopped		7	7.8	6.8- 9.6	—
Red oak	63	58	9.1	5.0-24.0	.51**
Dominant		5	15.3	11.2-24.0	—
Codominant		32	9.8	6.1-19.1	.08^N
Intermediate		14	6.9	5.3-10.6	.03^N
Overtopped		7	6.0	5.0- 9.2	—
White oak	63	31	10.2	5.0-18.9	.55**
Dominant		5	16.6	12.9-18.9	—
Codominant		14	10.8	7.5-16.7	.00^N
Intermediate		8	7.2	5.6-10.2	—
Overtopped		4	5.8	5.0- 6.8	—
Chestnut oak	63	151	9.6	5.1-23.5	.44**
Dominant		22	14.1	8.5-23.5	.00^N
Codominant		80	10.2	5.5-22.7	.00^N
Intermediate		30	7.3	5.2-14.2	.00^N
Overtopped		19	5.7	5.1- 7.6	.05^N
Chestnut oak	50	26	7.0	5.4-10.3	.19*
Dominant		—	—	—	—
Codominant		5	8.6	6.3-19.3	—
Intermediate		15	6.9	5.8- 8.5	.41*
Overtopped		6	5.9	5.4- 6.6	—
White oak	50	52	7.2	4.5-13.0	.42**
Dominant		—	—	—	—
Codominant		12	9.4	7.0-13.0	.03^N
Intermediate		25	7.2	5.0- 8.7	.30**
Overtopped		15	5.4	4.5- 6.2	.08^N

[1] Indicates the amount of d.b.h. growth variation accounted for by initial d.b.h. The correlation is always positive: the greater the initial d.b.h., the greater the d.b.h. growth rate.

*r is significant at the 5-percent level.

**r is significant at the 1-percent level.

^{N} r is not significant at the 5-percent level.

Table 6.—*Plot radius in feet for trees of given d.b.h.*

Tree d.b.h. (inches)	Horizontal distance that will include tree	
	40-factor	10-factor
	Feet	*Feet*
6	8.25	16.50
10	13.75	27.50
14	19.25	38.50
18	24.75	49.50
22	30.25	60.50
26	35.75	71.50

Table 7.—*Total basal area around study trees (includes trees over about 1.0 inches d.b.h.)*

Species	Crown class	Number of stems	Site index (oak)	Average basal area (1963)	
				10-factor	40-factor
Red oak	Dominant	7	85	110	109
	Codominant	30	85	123	149
	Intermediate	18	85	124	120
	Overtopped	13	85	127	151
Yellow-poplar	Dominant	18	85	118	118
	Codominant	22	85	130	142
	Intermediate	9	85	122	169
	Overtopped	4	85	130	120
Sugar maple	Dominant	4	85	—	—
	Codominant	3	85	97	80
	Intermediate	14	85	101	100
	Overtopped	40	85	128	133
Black cherry	Dominant	11	85	125	156
	Codominant	42	85	150	173
	Intermediate	21	85	153	189
	Overtopped	7	85	139	183
Red oak	Dominant	5	63	76	48
	Codominant	32	63	106	82
	Intermediate	14	63	111	103
	Overtopped	7	63	110	120
White oak	Dominant	5	63	76	56
	Codominant	14	63	103	69
	Intermediate	8	63	105	75
	Overtopped	4	63	108	100
Chestnut oak	Dominant	22	63	95	52
	Codominant	80	63	99	84
	Intermediate	30	63	100	100
	Overtopped	19	63	104	105
Chestnut oak	Dominant	0	50	—	—
	Codominant	5	50	110	104
	Intermediate	15	50	100	83
	Overtopped	6	50	90	100
White oak	Dominant	0	50	—	—
	Codominant	12	50	105	103
	Intermediate	25	50	113	114
	Overtopped	15	50	109	112

Table 8.—*Effect of initial density (10 and 40 factors) on 4-year d.b.h. growth—within a species and site class and regardless of tree crown class*

Correlation coefficients and r^2 with 4-year d.b.h. growth

Species	Site index (oak)	Number of sample trees	10-factor density		40-factor density		Difference in r^2 40-factor − 10-factor
			r	r^2	r	r^2	
Red oak	85	67	−0.15[N]	0.02	−0.19[N]	0.04	+.02
Yellow-poplar	85	51	−.32*	.10	−.36**	.13	+.03
Black cherry	85	81	−.06[N]	.004	−.09[N]	.008	+.004
Sugar maple	85	57	−.35**	.12	−.33**	.11	−.01
Red oak	63	58	−.26*	.07	−.33**	.11	+.04
White oak	63	31	−.55**	.30	−.34*	.12	−.18
Chestnut oak	63	151	−.29**	.08	−.33**	.11	+.03
Chestnut oak	50	26	−.15[N]	.02	−.18[N]	.03	+.01
White oak	50	52	+.12[N]	.02	+.12[N]	.01	−.01

* r is significant at the 5-percent level.
** r is significant at the the 1-percent level.
[N] r is not significant at the 5-percent level.

Table 9.—*Effect of initial total basal area on subsequent 4-year d.b.h. growth expressed in correlation* [1]

Species	Site index (oak)	Crown class	Number of sample trees	40-factor r with growth	basal area r^2
Red oak	85	Codominant	30	—0.37*	0.14
	85	Intermediate	18	—.01[N]	.00
Yellow-poplar	85	Dominant	18	—.36[N]	.13
	85	Codominant	22	—.28[N]	.08
Black cherry	85	Codominant	42	—.00[N]	.00
	85	Intermediate	21	—.10[N]	.01
Sugar maple	85	Overtopped	40	—.22[N]	.05
Red oak	63	Codominant	32	—.15[N]	.02
Chestnut oak	63	Dominant	22	—.39[N]	.15
	63	Codominant	80	—.13[N]	.02
	63	Intermediate	30	—.19[N]	.04
	63	Overtopped	19	+.03[N]	.00
Chestnut oak	50	Dominant	0	—	—
	50	Codominant	5	—	—
	50	Intermediate	15	—.05[N]	.003
	50	Overtopped	6	—	—
White oak	50	Dominant	0	—	—
	50	Codominant	12	—	—
	50	Intermediate	25	—.01[N]	.00
	50	Overtopped	15	+.51*	.26

[1] Analyses made for groups containing at least 15 trees.
* r is significant at the 5-percent level.
[N] r is not significant at the 5-percent level.

Table 10.—*Annual d.b.h. growth of species, site quality, and crown class*

Species	Dominant crown class		Codominant crown class		Intermediate crown class		Overtopped crown class	
	Annual d.b.h. growth in inches	Number of trees	Annual d.b.h. growth in inches	Number of trees	Annual d.b.h. growth in inches	Number of trees	Annual d.b.h. growth in inches	Number of trees
			SITE INDEX 50					
White oak								
Mean	—	—	0.071	12	0.056	25	0.024	15
Confidence limits	—		0.085-0.057		0.066-0.046		0.033-0.015	
Chestnut oak								
Mean	—	—	0.082	5	0.073	15	0.060	6
Confidence limits	—		0.099-0.065		0.081-0.065		0.074-0.046	
Scarlet oak								
Mean	0.093	7	0.070	32	0.058	8	—	—
Confidence limits	0.114-0.072		0.080-0.060		0.069-0.047		—	
			SITE INDEX 63					
White oak								
Mean	0.187	5	0.154	14	0.130	8	—	—
Confidence limits	0.242-0.132		0.187-0.121		0.183-0.777		—	
Chestnut oak								
Mean	0.185	22	0.145	80	0.108	30	0.066	19
Confidence limits	0.216-0.154		0.153-0.137		0.124-0.092		0.083-0.049	
Red oak								
Mean	0.262	5	0.248	32	0.170	14	0.130	7
Confidence limits	0.318-0.206		0.270-0.226		0.202-0.138		0.150-0.101	

Red maple								
Mean	—	—	0.212	8	0.131	14	0.095	12
Confidence limits	—		0.282-0.142		0.157-0.105		0.112-0.078	
			SITE INDEX 85					
Red oak								
Mean	0.377	7	0.280	30	0.174	18	0.081	13
Confidence limits	0.425-0.329		0.308-0.252		0.209-0.139		0.112-0.050	
Sugar maple								
Mean	—	—	—	—	0.163	14	0.125	40
Confidence limits	—		—		0.195-0.131		0.147-0.103	
Black cherry								
Mean	0.148	11	0.153	42	0.098	21	0.059	7
Confidence limits	0.178-0.118		0.168-0.138		0.122-0.074		0.083-0.035	
Yellow-poplar								
Mean	0.210	18	0.173	22	0.120	9	—	—
Confidence limits	0.237-0.183		0.196-0.150		0.151-0.089		—	
White ash								
Mean	—	—	0.197	13	0.125	10	—	—
Confidence limits	—		0.218-0.176		0.172-0.078		—	
Sweet birch								
Mean	—	—	—	—	0.141	15	0.110	9
Confidence limits	—	—	—		0.171-0.111		0.164-0.056	

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

HYDROLOGIC EFFECTS *from* URBANIZATION *of forested watersheds in the Northeast*

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by Howard W. Lull
and William E. Sopper

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

THE AUTHORS

HOWARD W. LULL, a forest-hydrologist, received his bachelor of science degree in forestry from North Carolina State College in 1938, his master of forestry degree from Yale University in 1939, and a Ph.D. from the University of Maryland in 1956. His background includes a year's employment with the Tennessee Valley Authority Department of Forestry Relations, and 3 years' employment with the Soil Conservation Service, U. S. Department of Agriculture. He joined the U.S.D.A. Forest Service in 1946, and worked at the Intermountain and Southern Forest Experimental Stations before transferring to the Northeastern Forest Experiment Station in 1956.

WILLIAM E. SOPPER, professor of forest hydrology at the School of Forest Resources, The Pennsylvania State University, received his bachelor of science degree in forestry from Penn State in 1954, his master of forestry degree—also from Penn State—in 1955, and a Ph.D. in forest hydrology from Yale University in 1960. His background includes two summers as a research forester at the Northeastern Forest Experiment Station. He became an instructor in forestry at the Mont Alto Campus of Penn State in 1955 and transferred back to the main campus at University Park in 1958.

HYDROLOGIC EFFECTS *from* URBANIZATION *of forested watersheds in the Northeast*

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A CHANGING ENVIRONMENT

URBANIZATION, particularly in the crowded Northeast, has created a new environment. Asphalt and concrete have replaced hundreds of square miles of soil, buildings have replaced trees on much of the land, and sewers have replaced streambeds in many areas. As a result, the hydrology of this land is changing rapidly.

To determine the effects of this expanding urbanization on forested watersheds, the Northeastern Forest Experiment Station has studied streamflow records of forested and urbanized watersheds. This paper is a report of that study.

We consider first the urban and forest environments in relation to their differing effects on several hydrologic processes and on water quality. Second, we estimate the effects of urbanization on evapotranspiration and runoff by theoretically imposing urban conditions on a forested watershed for which climatic and streamflow records are available. Third, we describe the effects of actual progressive urbanization on peak flows, stormflows, and annual runoff of three Northeastern watersheds; and we compare peak flows, percentage of runoff, high- and low-flow intervals, and hydrologic responses between four partially urbanized and nine mostly forested watersheds.

Urbanization—the swelling of cities, the sprawling of suburbs, and the blossoming of beltways—is the most revealing effect of our continuing population explosion. In the third century, Rome occupied an area of slightly more than 5 square miles; now it occupies 580 square miles. In the fourteenth century, London covered slightly more than 1 square mile; now it covers about 700 square miles. And metropolitan New York, which had only scattered settlements 300 years ago, now covers more than 2,500 square miles *(Mumford 1956)*.

The 12 States of the Northeast are the most densely populated in the United States: their 251 people per square mile far exceed the 128 in the Lake States, the 99 in California, and the 73 in the Southeast. And cities in the Northeast are beginning to coalesce: three-fourths of the population live in one-fourth of the region, the Megalopolis that stretches 500 miles from Washington to Boston and includes Baltimore, Philadelphia, and New York (fig. 1). In this area the population density has increased to 700 people per square mile.

Most of the population outside Megalopolis is also urbanized —in nine metropolitan areas, of which the largest are Pittsburgh-Johnstown-Altoona, Syracuse-Utica-Rome, and Albany-Schenectady-Troy. Twenty-one percent of the land area of the Northeast is classified by the U. S. Bureau of Census as standard metropolitan statistical areas with populations of more than 100,000. Metropolitan areas range from 0 to 61 percent of total state area:

	Percent		*Percent*
Vermont	0.0	New York	26
New Hampshire	.1	Massachusetts	32
Maine	.2	Connecticut	35
West Virginia	9.4	Pennsylvania	35
Delaware	19	New Jersey	52
Maryland	25	Rhode Island	61

As the cities have grown, they have spread over farm and forest. Between 1942 and 1956, about 230,000 acres of cultivable land in New England and 1,150,000 acres in the Middle Atlantic States were converted to nonagricultural uses. An estimated 238 acres of fields and trees have been engulfed for each increase of 1,000 in urban population *(Bogue, 1956)*.

Most of this land was converted to residential areas, roads, and public-use areas. Mean proportions of areas devoted to various uses in 14 large Northeastern cities were calculated from Niedercorn and Hearle's *(1963)* data, as follows:

	Percent
Residential	28
Road and highway	25
Other public	20
Vacant	12
Industrial	11
Commercial	4

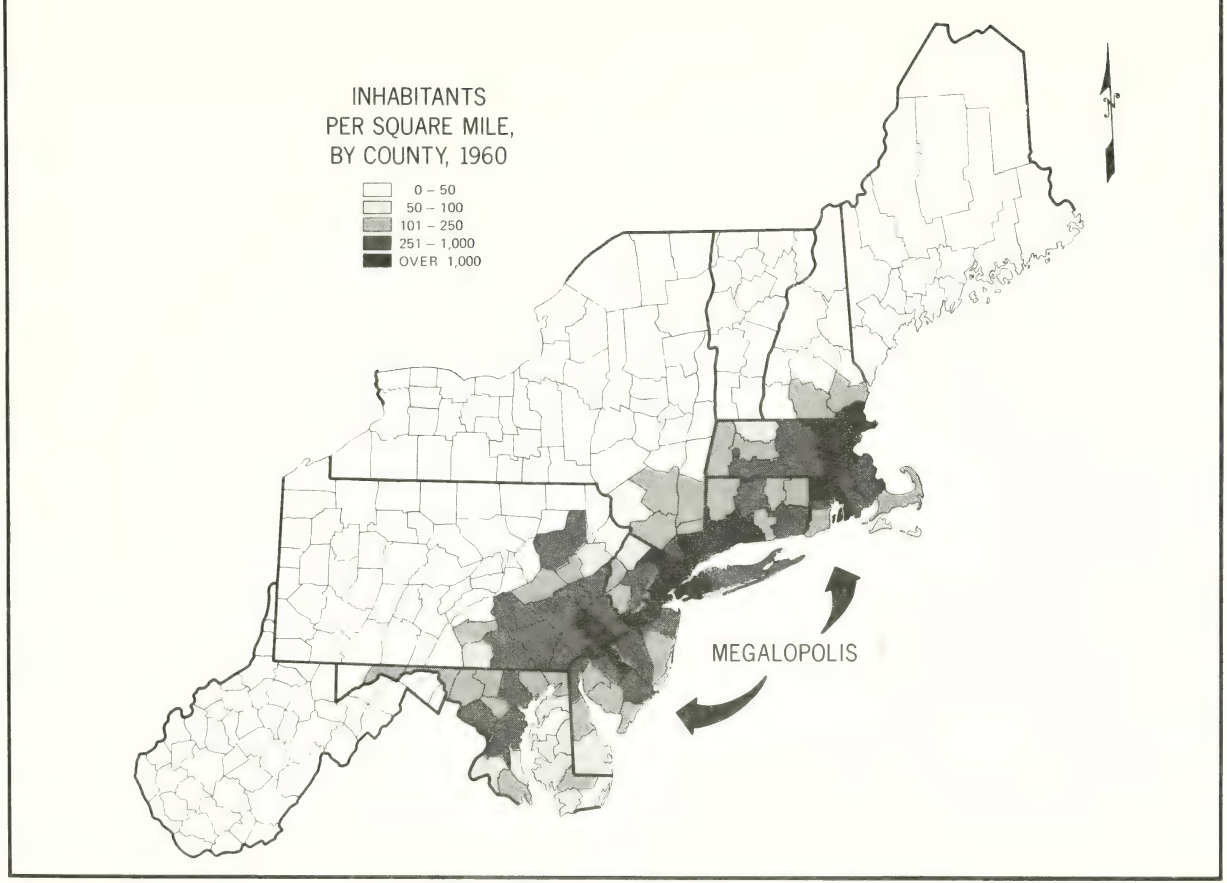

Figure 1.—The Megalopolis of the Northeast.

Conversion of farm and forest to residential areas, roads, parking lots, lawns, and other urban uses obviously should have major effects on the hydrology of the area—specifically, on the distribution of precipitation to evapotranspiration, to soil-moisture storage, and to runoff. The degree of influence will depend on the degree of urbanization, expressed most simply as the proportion of the area covered with an impervious surface. This can range from almost 100 percent in commercial districts to a small percentage in suburban areas. Antoine *(1964)* gave these percentages of impervious area for various urban land uses:

	Percent
Cemeteries	5
Parks and recreation	15
Residential lot area:	
15,000 square feet	25
6,000 to 14,999 square feet	40
5,999 square feet	80
Semipublic and public	75
Industrial	90
Commercial	100

In other estimates, impervious areas were found to occupy 30, 50, and 72 percent of three city blocks in St. Louis *(Horner and Flynt 1936),* and impervious areas were estimated to cover about 50 percent of Brooklyn *(Thomas 1956).*

Suburbs have smaller proportions of impervious areas than city areas. For instance, the mean proportions of areas occupied by rooftops, pavement, and lawn in Philadelphia suburbs were estimated by Felton and Lull *(1963):*

Size of lot (acres)	*Rooftops (percent)*	*Pavement (percent)*	*Lawns (percent)*
1.8	2	6	92
.5	6	11	83
.4	8	18	74
.2	12	20	68

Proportionately, rooftops and pavements occupied four times as much area in the smallest lot as in the largest. Carter *(1961)* found the percentage of impervious surface area in suburban Washington, D. C., to be about 12 percent. Probably the largest paved areas in the suburbs, exclusive of streets, are the modern

shopping centers, which require three to four times as much space for car parking as for merchandising floor area.

What has happened to the hydrology of the areas on which houses, lawns, streets, and commercial and industrial areas have replaced farm and forest? One way to find out is to compare urban hydrology to forest hydrology, using a protected forest as the base condition or control. That is what we have done. Results from research in forest hydrology conducted during the past 40 years and in urban hydrology conducted, for the most part, over the past 20 years were used to facilitate this comparison.

HYDROLOGIC PROCESSES

The hydrologic processes that we consider briefly below are interception, infiltration and overland flow, soil-moisture storage, evapotranspiration, runoff, and peak flows.

Interception

Hardwood and conifer canopies in the Northeast intercept and evaporate about 15 to 20 percent of the growing-season rainfall before it reaches the forest floor. In winter, hardwoods intercept about 7 percent of the precipitation and conifers about 18 to 25 percent, depending upon how much precipitation occurs as snow. For example, of an average annual precipitation of 45 inches in central Massachusetts, hardwoods intercept about 5 inches and conifers about 9 inches, respectively 11 and 20 percent of the annual precipitation *(Lull 1967)*.

City streets can intercept and store on their surfaces perhaps 0.04 to 0.10 inch of water *(Viessman 1966)*. The amount of precipitation intercepted by roofs and sides of urban buildings, and evaporated from them, has probably never been estimated; but it is very likely less than 0.04 inch. In light of the great variety of construction that protrudes from city surfaces, any estimates would be highly speculative. For example, a city block of 1 acre occupied by a 10-story building would have about 2 acres in sidewalls, which would give an interception surface-area to ground-area ratio (including roof) of 3:1. In comparison, leaf areas, (both sides) of forest canopies have ratios that range from 2:1 to 9:1

(Kittredge 1948). If the sidewalls (only partially wetted) could intercept 0.01 inch of rainfall and the roof 0.04 inch, and if 120 rainfalls occurred during a year amounting to 45 inches precipitation, 16 percent would be intercepted—about the percentage intercepted by trees in summer.

Residential areas, where the principal intercepting areas are lawns, would intercept somewhat less. From measurements of grass interception by Burgy and Pomeroy *(1958),* we estimate a lawn 2 inches high could intercept about 0.01 inch of water. And if we add to this an estimated depression storage of 0.04 inch for the entire area, the total residential-area interception would be about 0.05 inch or, in relation to the 45-inch annual rainfall noted above, a total annual interception of about 13 percent.

Infiltration and Overland Flow

Infiltration in the undisturbed forest is generally assumed to be at rates greater than rainfall intensities. Undisturbed litter and humus and underlying soil beneath the forest canopy are immediate evidence that overland flow has not occurred. However, on disturbed areas such as logging roads and skid trails where soil has been compacted, evidence of overland flow is common; and infiltration in such areas obviously is often at rates lower than rainfall intensities. In general, these areas constitute 10 to 20 percent of the area logged.

In urban areas, infiltration can range from zero for paved areas and roofs to rates exceeding rainfall intensities in those uncommon, soil-covered areas not subject to traffic by vehicles or people. Lawns have surprisingly low infiltration capacities because their soils have often been man-mixed, bulldozed into position, and compacted by frequent mowing and trampling. In one study, ring-infiltrometer tests showed that an average of 0.10 inch of water infiltrated per minute into lawns and 0.58 inch into forest soil *(Felton and Lull 1963).*

As noted above, overland flow is generally absent in the undisturbed forest. On urban areas that are completely paved or roofed, overland flow from any rainfall will equal rainfall less

surface retention (the volume required to wet all surfaces, depression storage, and evaporation during rainfall). Annually, the runoff might constitute 85 percent of the precipitation. This has been confirmed by several reports on small watersheds that were paved or sprayed with asphalt to collect the precipitation for water supply *(Chinn 1965; Myers and others 1967).*

In other areas runoff will depend on the proportion of the surface that is impervious. For instance, Horner and Flynt *(1936)* found that for small urban areas in St. Louis the average ratio of runoff rates to rainfall rates was 0.4 for an area that was 30 percent impervious, 0.65 for a 50-percent impervious area, and 0.8 for a 72-percent impervious area. Under high-intensity rainfall, lawns can produce considerable overland flow. Horner and Flynt *(1936)* also found that sprinkling sodded plots at the rate of 2.5 inches per hour resulted in runoff rates of 1.60 and 2.00 inches per hour 30 to 40 minutes after overland flow began.

Soil-Moisture Storage

In the Northeast, most of the forest is limited to hilly and mountainous areas typified by fairly coarse-texture soils that range from 2 to 5 feet in depth. Starting from a dry state, these soils could retain 4 to 10 inches of water. Their storage potential, particularly during the frequent dry periods in summer, is such that very little summer precipitation reaches streamflow or the groundwater table.

In urban areas, storage is considerably less, ranging from 0.04 inch of depression storage on paved areas to greater amounts in lawns and parks. Brater *(1968)* calculated interception and storage of 0.2 inch for permeable portions of three drainage basins in the Detroit metropolitan area. Hicks *(1944)* found in Los Angeles that about 10 percent of the average rainfall was lost to storage, and portions of this went into sewer manholes and basements.

Evapotranspiration

Annual forest evapotranspiration in the Northeast ranges from about 23 inches in New England to 29 inches in the Coastal Plain

of Delaware and Maryland *(Lull 1968)*. Evapotranspiration is at a maximum for forest areas because of their complete occupancy of an area, and their low albedo, deep roots, and interception.

On impervious urban areas that receive an annual rainfall of 40 to 50 inches, evaporation can range from 4 to 5 inches a year or on an estimated 10-percent storage of annual rainfall, based on estimated depression storage and number of rainfalls.

In residential areas, summer runoff from roofs and sidewalks that infiltrates into lawns can add to the water available for evapotranspiration. Water used for sprinkling lawns and gardens can also greatly increase it. For instance, in Pasadena, California, Gleason *(1952)* estimated annual evapotranspiration for impervious areas to be about 4 inches of water; for residential areas, 24 inches; and for areas of lawns and trees, 36 inches or more. Annual precipitation was about 20 inches in this area.

Runoff

Runoff from forested watersheds in the Northeast ranges from about 24 inches in mountainous New England to about 15 inches in the southern part of the region. Compared with urban runoff, forest runoff is reduced by greater interception, higher infiltration, less overland flow, greater soil-moisture storage, and higher evapotranspiration. Two studies have shown that the conversion of forest land to urban use increases the amount of precipitation that appears as runoff. Urbanization of a small forested watershed near Seattle, Washington, increased the proportion of rainfall that appeared as daily discharge about three times: from 0.099 to 0.296 c.f.s. per inch of rainfall *(Wooldridge 1967)*. And in an East African study, runoff from the largest storms on a 31-acre forested area amounted to less than 1 percent of the rainfall as contrasted with runoff from a 32-acre housing and administrative area, where runoff was 36 percent of rainfall *(Dagg and Pratt 1962)*.

Rough estimates of the distribution of annual rainfall in a Northeastern hardwood forest, and in Northeastern urban areas with 50- and 10-percent impervious covers, were as follows:

	Forest (inches)	*50-percent impervious (inches)*	*100-percent impervious (inches)*
Precipitation	40	40	40
Interception	5	3	2
Overland flow	(0)	(18)	(36)
Soil-moisture storage	(6)	(3)	(2)
Evapotranspiration	15	12	2
Runoff	20	25	36

Values in parentheses indicate temporary storage: soil-moisture in storage would presumably be evapotranspired and overland flow would become runoff. In the 50-percent impervious area, 18 inches were estimated as overland flow, of which one-fourth, 4.5 inches, were assigned to growing-season evapotranspiration from pervious areas; this amount, plus 7.5 inches of evapotranspiration from the pervious area, accounts for the total of 12 inches.

The effect of urbanization on runoff would also depend on precipitation and evapotranspiration of the area. Where evapotranspiration is greater than in the Northeast, runoff would be less but the percentage change in runoff due to urbanization would be greater. Variable results might be expected. James (1965) estimated from a California streamflow record that over a 10-year period the runoff volume from a completely urbanized watershed was 2.29 times the volume from the same watershed when it was in a rural condition.[1] In Austin, Texas, runoff increased 1.9, 2.1, and 2.4 times for watersheds with 21-, 27-, and 38-percent impervious cover *(Espey and others 1965)*, respectively.

Peak Flows

Peak flows from undisturbed forest watersheds are minimized by high-infiltration capacities and absence of overland flow. However, under wet conditions, high rates of runoff can be produced from subsurface flow.

Studies of increases in peak flows with progressive urbanization, or comparisons of peak flows from small urban and rural water-

[1] The term "rural" designates an open-land nonforest condition in this study, and also in the Mississippi study *(Wilson 1967)* and the Texas study *(Van Sickle 1962-63)*. Pre-urbanization land use for the other studies referred to in this respect was not given.

sheds, suggest that urbanization increases peak flows by 1.2 to 5 times. As examples, suburban developments in Washington, D. C., which increase the impervious area by 12 percent, can increase flood peaks by 1.8 times *(Carter 1961)*. In Long Island, peak discharges with an occurrence interval of 1.15 years increased 2.3 times during a 21-year period of progressive urbanization *(Sawyer 1961)*. In New Jersey, Potter *(1957)* found that the actual maximum annual peak for a 10-year recurrence interval was 1.5 times greater than the peak derived from a regional prediction procedure based on watershed areas and a rainfall index. At Jackson, Mississippi, mean maximum annual flood peaks for a totally urbanized basin were about 4.5 times those for a similar but rural stream *(Wilson 1967)*.

A model analysis of a California streamflow record has shown that urbanization increased flood peaks an estimated 1.6 to 2.3 times *(James 1965)*. And studies in Texas and Michigan *(Van Sickle 1962-3; Espey and others 1965)* indicate flood peaks from urban watersheds were two to five times greater than those from rural watersheds. According to Waananen *(1961)*, peak runoff from developed areas in northern New Jersey, Michigan, Pennsylvania, and Virginia averages three to four times greater than that from upstream or adjacent natural areas. Urbanization of a watershed in the northern part of Tokyo in 1958-66 increased flood peaks by a factor of three *(Kinosita and Sonda 1967)*.

Design peak runoff rates calculated by the rational method for urban and forest conditions give somewhat greater ratios. Peaks from urban areas 30-percent impervious were estimated to be four times greater than peaks from flat areas of woodland on open sandy loam; for 50-percent impervious areas they were 5.5 times greater; and for 70-percent impervious areas they were 6.5 times greater *(Schwab and others 1957)*.

Leopold *(1968)* synthesized data from several studies to show the increase in the average annual flood for degrees of urbanization, defined by increases in percentage of areas sewered and made impervious:

Percentage of area sewered	*Percentage of area impervious*	*Ratio to average annual flood*
0	0	1
20	20	1.5
40	40	2.3
50	50	2.7
80	60	4.2
100	60	4.4

Comparison of peak flows from the Dagg and Pratt *(1962)* East African study in which discharges from a forested watershed and an urbanized area were measured, show even greater differences. From 31 storms the ranges of peak flows were:

Forested area		*Housing nad administrative area*	
Storms (No.)	*Peak flow (c.s.m.)*	*Storms (No.)*	*Peak flow (c.s.m.)*
18	0.01 to 0.1	2	1.0 to 10
11	0.1 to 1.0	10	10 to 100
2	1.0 to 10	18	100 to 1,000
—	— —	1	1,000 to 10,000

Water Quality

Stages in the transition of forest and farm land to urban areas and the hydrologic effects of these changes have been described by Savini and Kammerer *(1961)*. The resultant marked increases in sedimentation have been most strikingly demonstrated by studies in the vicinity of Washington, D. C., and Baltimore, Md., where land clearing for suburban construction has produced record sedimentation rates. After a review of these studies, O'Bryan and McAvoy *(1966)* concluded that sediment yields that can be expected from the 350-square mile Gunpowder Falls basin, under various land uses were as follows:

	Sediment (tons per square mile per year)
Forest land	About 50
Urban and suburban land	50 to 100
Farmland	1,000 to 5,000
Land stripped for construction	25,000 to 50,000

For an average annual runoff of 15 inches, the maximum turbidities for the above sediment yields, in parts per million, are 45,

90, 4,500, and 45,000. Recommended maximum turbidity for drinking water is 5 p.p.m.

The above estimate of 50 tons per square mile per year or 45 p.p.m. may be high for sedimentation from a protected forest watershed. Streamflow from a protected forest is generally prized for its purity, and its turbidity rate may generally be well below the drinking-water standard. For instance, streamflow from second-growth forested watersheds at the Fernow Experimental Forest in West Virginia had an average turbidity under 5 p.p.m. *(Reinhart and others 1963),* equivalent to 9 tons of sediment or less per square mile per year. In Kentucky, sediment yield from a small heavily forested watershed was 15 tons per square mile per year *(Wolman and Schick 1967).*

In New Jersey, Anderson and McCall *(1966)* found that suspended-sediment varied with topography and land use. Forest flatland had yields of 10 to 40 tons per square mile annually; moderately heavily urbanized areas on flatland, 25 to 100 tons; forest upland, 25 to 100 tons; and heavily urbanized upland, 75 to 500 tons.

For a representative selection of rural watersheds in Maryland, Wolman and Schick *(1967)* showed a range in sediment yield of 200 to 900 tons per square mile per year as compared with a yield of 1,000 to 140,000 tons per square mile per year from areas undergoing construction around Washington, D. C., and Baltimore.

Urban areas under construction can thus become bountiful sources of sediment, especially where modern earth-moving equipment reshapes soil into building lots that remain unprotected. According to Holeman and Geiger *(1959),* such areas may remain bare for about 3 months for a single dwelling construction; and large housing and apartment developments may expose soil more than a year. An analysis of building permits issued in Baltimore County showed that 40 percent of the sites were open for more than 9 months, and 25 percent were open for more than 1 year *(Wolman and Schick 1967).*

A notorious example of erosion is the Lake Barcroft area near Washington, D. C., where 25,000 tons of sediment have been

deposited for each square mile of residential construction *(Guy and Ferguson 1962)*. In another housing project in the same area, Guy *(1963)* estimated that the sediment load for the construction period was equivalent to 121,000 tons per square mile—equivalent to removal of about 1.2 inches of soil. In metropolitan Baltimore County, Wolman and Schick *(1967)* estimated that about 1,800 tons of sediment were produced per 1,000 increase in population, and for Prince Georges County, near Washington, a yield of 700 tons per 1,000 increase.

As noted earlier, once construction is completed, sedimentation rate of urban and suburban areas may drop to 50 to 100 tons per square mile, but this is still 5 to 10 times the rate from protected forested watersheds such as at the Fernow Experimental Forest in West Virginia.

Careless logging practices can also quickly produce turbid flow and substantial quantities of sediment. For instance, over a period of 1 year at the Fernow Experimental Forest, careless logging produced an average turbidity of 490 p.p.m., or 862 tons of sediment per square mile, and an instantaneous peak turbidity of 56,000 p.p.m. Without remedial measures, the average turbidity dropped to 38 p.p.m. the first year after logging and to 1 p.p.m. the second year after logging. This rapid self-healing, perhaps characteristic of stony forest soils in the Northeast, was due to the development of an erosion pavement and the invasion of vegetation on the logging roads.

URBANIZATION EFFECTS ON SMALL FORESTED WATERSHEDS

As the foregoing discussion of hydrologic processes indicates, urbanizing a forested watershed will reduce evapotranspiration, increase runoff, and increase peak flows. Other things being equal, the magnitude of these effects will depend on the degree of urbanization, or, at its simplest, the proportion of the watershed that is rendered impervious. To demonstrate these effects, streamflow and climatic records of a small forested watershed were utilized.

Streamflow and climatic records from the Dilldown Watershed in Pennsylvania *(McQuilkin and others 1956)* were used to estimate evapotranspiration and runoff effects. This 1,529-acre experimental watershed possessed a forest cover largely of scrub oak. Water-year 1953 was selected as being representative of the 10 years of published records. We computed daily potential evapotranspiration by the Hamon procedure *(Hamon 1963);* and we estimated runoff from the daily record of precipitation and an estimated soil-moisture content with a total 6-inch storage.

Precipitation for the water-year measured 58.06 inches and runoff 36.50 inches; and their difference, estimated evapotranspiration, was 21.56 inches. Estimated potential evapotranspiration from a daily water balance was somewhat greater, 26.0 inches; and estimated runoff was somewhat less, 35.0 inches. But there was sufficient similarity to justify using these procedures to illustrate the effects of three degrees of urbanization.

Daily water balances were computed, simulating a watershed that was 25-, 50-, and 75-percent impervious. On the impervious area, a depression storage of 0.04 inch for each daily rainfall was assumed evaporated; except for this, potential evapotranspiration was assumed to be zero. Runoff from the paved surfaces was assumed to empty directly from conduits into streamflow.

Estimated annual and seasonal potential evapotranspiration and runoff from forested and impervious areas are given in table 1.

Annual potential evapotranspiration was reduced 19, 38, and 59 percent by 25-, 50-, and 75-percent impervious cover, respectively. In each of the four examples (including the 100-percent forested area), about three-fourths of the potential evapotranspiration occurred during the 6-month growing season (April through September). Almost equal evapotranspiration from the impervious area, by season, reflects similarity in number of days of precipitation: 71 during the growing season and 75 in the dormant season.

Annual runoff increased by 15, 29, and 41 percent with increases of impervious area. In the completely forested area, 80 percent of the runoff occurred during the dormant season. In the urbanized area the distribution was more uniform: with a 75-percent im-

Table 1.—*Estimated potential evapotranspiration and runoff (annually and seasonally), in inches*

Period	100-percent forest	75-percent forest	25-percent impervious	50-percent forest	50-percent impervious	25-percent forest	75-percent impervious
				POTENTIAL EVAPOTRANSPIRATION			
Annual	26.0	19.6	1.4	13.0	2.9	6.2	4.3
Growing season	20.1	15.1	.7	10.0	1.4	5.0	2.1
Dormant season	5.9	4.5	.7	3.0	1.5	1.2	2.2
Total annual	26.0	21.0		15.9		10.5	
				RUNOFF			
Annual	35.0	26.2	14.1	17.5	27.6	8.8	40.5
Growing season	7.0	5.2	5.9	3.5	11.5	1.8	16.9
Dormant season	28.0	21.0	8.2	14.0	16.1	7.0	23.6
Total annual	35.0	40.3		45.1		49.3	

pervious cover, 62 percent of the runoff occurred in the dormant season.

In a similar comparison for the South Branch of the Raritan River in New Jersey, Muller *(1968)* estimated an evapotranspiration of 23.0 inches and a runoff of 24.0 inches for the basin in its rural condition. And he estimated that if one-half of the basin were rendered impervious by urban surfaces, evapotranspiration would be reduced to 11.5 inches and runoff increased to 35.5 inches, changes proportionate to those estimated for the Dilldown Watershed (table 1). Here again the estimated increases occurred mostly during the summer months.

URBANIZATION EFFECTS ON STREAMFLOW RECORDS

After studying the effects of urbanization on individual hydrologic processes and calculating their effects on runoff, we wondered if the influence of urbanization on streamflow could be detected by analyses of actual surface water records. We tried two approaches. The first involved three watersheds that were increasingly urbanized during the past 24 to 35 years. In this analysis, maximum annual peak flows, annual ratios of stormflow to precipitation (hydrologic response), and deviations of actual runoff from predicted runoff were plotted and examined for trends. The second method involved comparisons of various parameters of streamflow for four partially urbanized watersheds and nine mostly forested watersheds, calculated for the period 1940 to 1957. All watersheds studied were less than 100 square miles in area.

Progressive Urbanization

Annual maximum peak flows, annual hydrologic responses, and annual runoff deviations are shown in figure 2, and their regression trends are given in table 2. Annual maximum peak flows are the momentary peaks. Hydrologic responses are the ratios of annual stormflow to annual precipitation, calculated according to the procedures described by Hewlett *(1967)*. Runoff deviations

Table 2.—*Trends in peak flows, hydrologic responses, and annual runoff deviations on progressively urbanized watersheds.*

Watershed	Period	Area	Urban area[1]	Regression trends (slope coefficients)		
				Peak flows	Hydrologic response	Annual runoff deviations
		Square miles	*Per-cent*	*C.f.s. per year*	*Stormflow per precipitation per year*	*Inches per year*
Weasel Brook, N. J.	1938-62	4.45	98	10**	[2] 0.0063**	[2] 0.93**
Second River, N. J.	1938-64	11.6	98	4	.0019*	.18
Rock Creek, Md.	1930-65	62.2	25	17	.008*	.07

[1] From U.S. Geol. Surv. topographic quads 1955 for Weasel Brook and Second River, and 1956 for Rock Creek.
[2] For 1948-62.
**Regression slope significantly different from zero at 1-percent level.
* Regression slope significantly different from zero at 5-percent level.

Figure 2.—Peak flow, hydrologic response, and annual runoff deviations of progressively urbanized watersheds, and their trends.

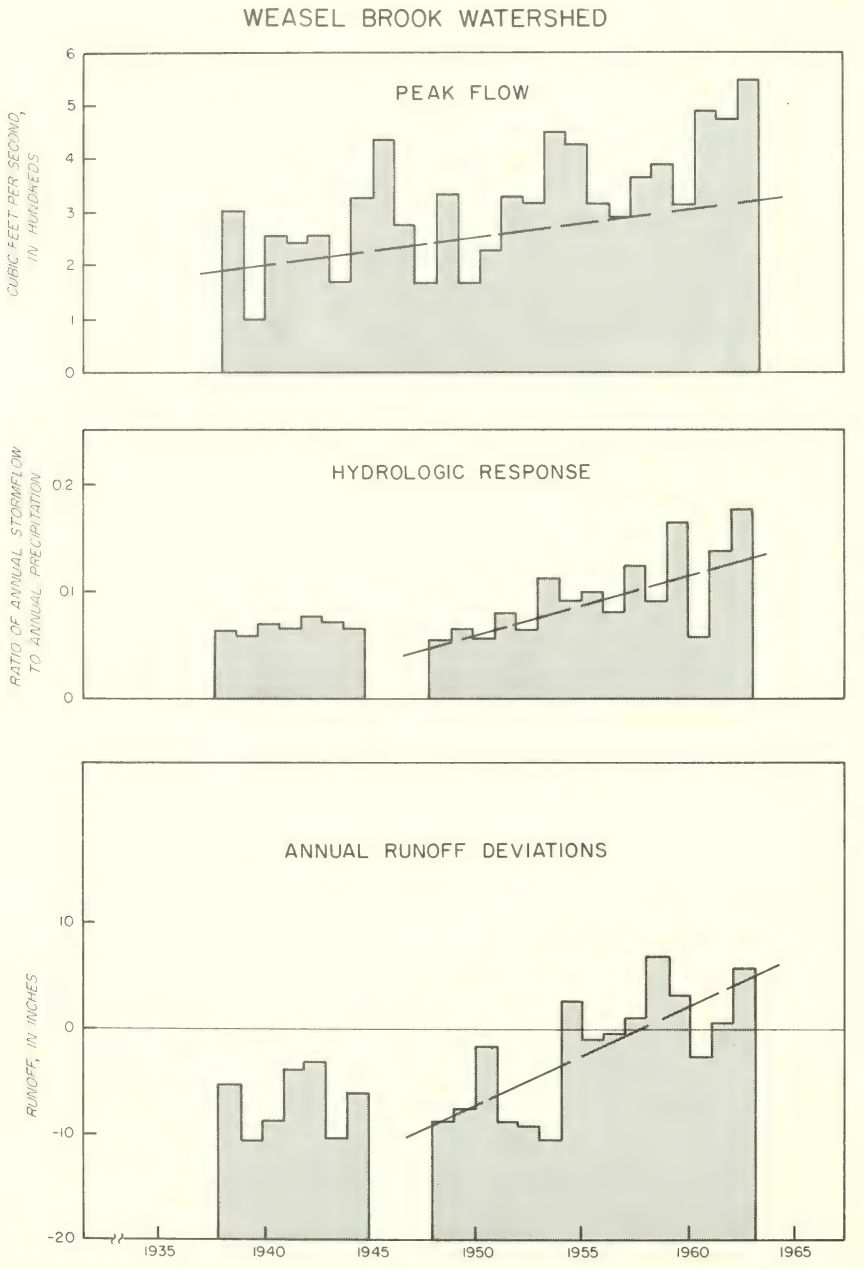

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Figure 2.—Continued

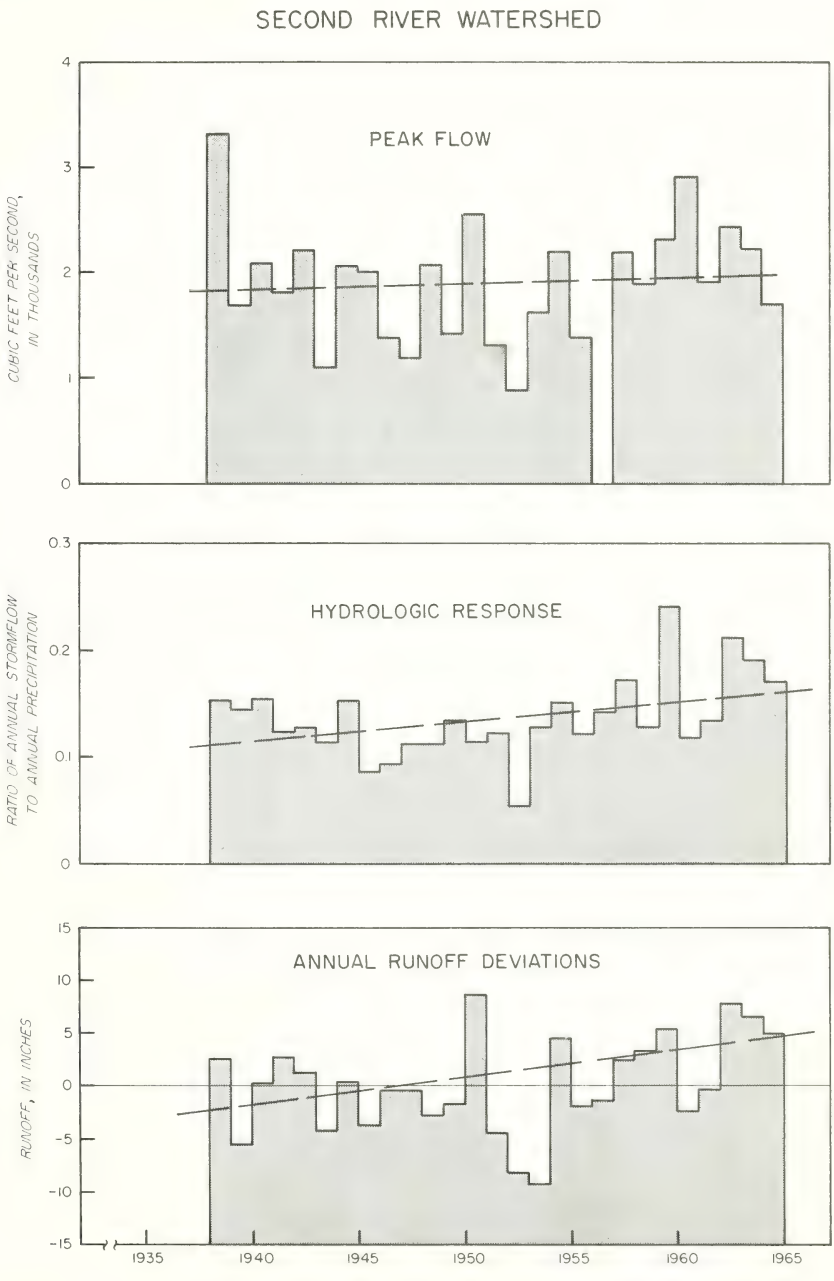

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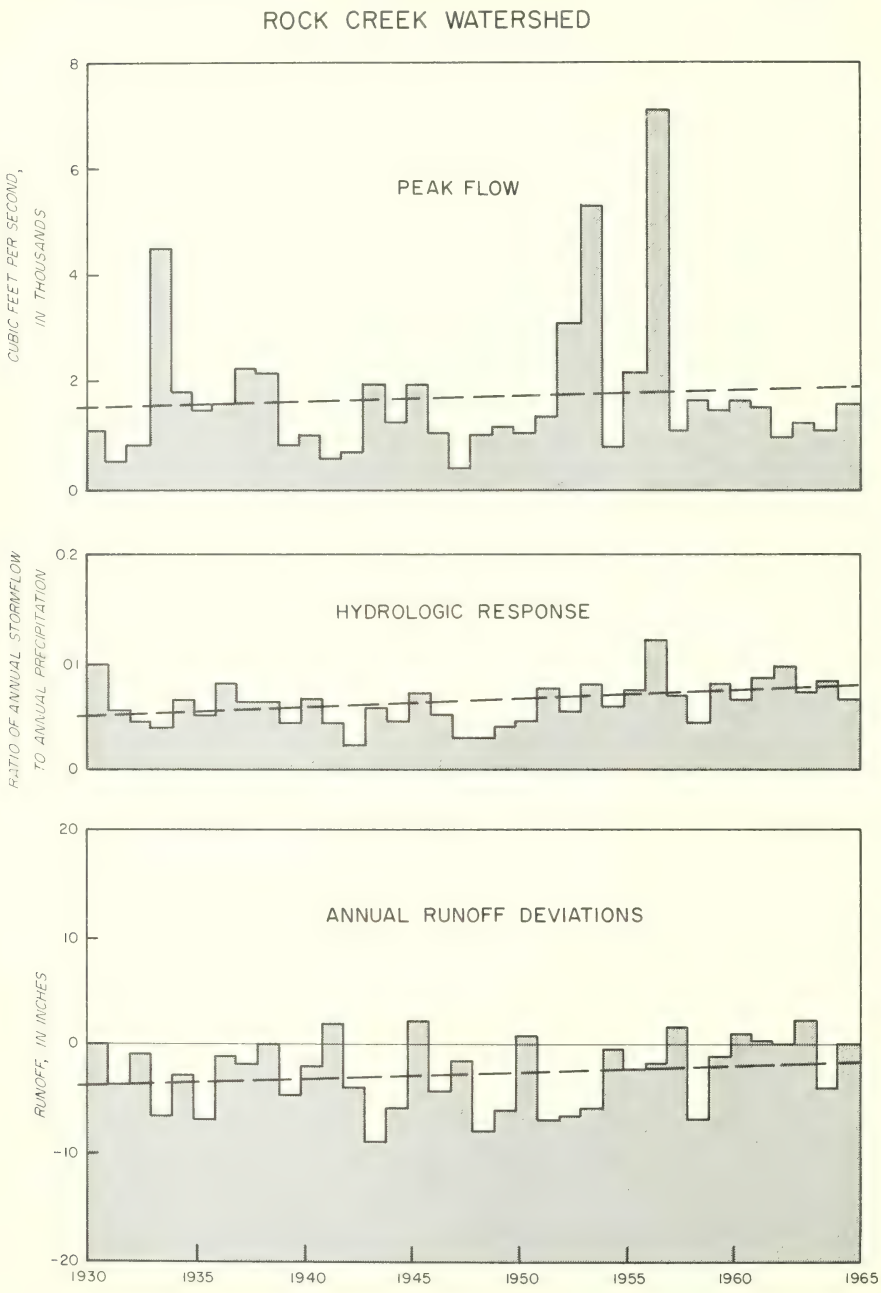
Figure 2.—Continued



are the differences between actual annual runoff and predicted annual runoff, the latter obtained from a computer program devised by Black *(1967)* for the Thornthwaite and Mather *(1957)* method for computing the annual water balance.

All nine linear regressions indicated increasing peak flow, stormflow, and annual runoff during the periods of increasing urbanization; five of the regressions had slopes statistically significantly different from zero. Weasel Brook, the smallest watershed, showed the greatest reaction: peak flows increased about 2 c.s.m. per year during the 25-year period and annual runoff increased almost 1 inch per year during the 15-year period. Annual ratios of stormflow to precipitation appeared to be the most sensitive indicator of urbanization.

Partially Urban vs. Forested Watersheds

This comparison was limited to the southern New England region. We used two approaches. In the first approach, for 1940-57, mean maximum annual momentary discharge and mean maximum annual daily discharge over 10 c.s.m., and the number of such discharges, were calculated for six watersheds where high flows were not regulated. In the second approach, streamflow parameters other than maximum discharges were analyzed; this involved analyses of records from the same six watersheds plus records from seven watersheds where flow was regulated to some degree by power plants and reservoirs. Locations of the 13 watersheds are shown in figure 3.

The analyses involved calculations of: (1) the percentage of annual and summer (June-August) precipitation that appeared as runoff; (2) the shortest number of consecutive days required to produce 50- and 25-percent annual discharge (high-flow intervals), and the greatest number of consecutive days to produce 1- and 5-percent annual discharge (low-flow intervals), using Satterlund and Eschner's *(1965)* procedure; and (3) the hydrologic responses for the 1957-59 period. Results are given in tables 3 and 4.

Table 3.—*Mean maximum annual momentary peak flows and mean annual daily discharges over 10 c.s.m., 1940-57*

Watershed	Area	Land use			Mean annual momentary peak	Daily discharge over 10 c.s.m.	
		Forest	Open	Urban		No.	Mean
	Square miles	*Pct.*	*Pct.*	*Pct.*	*C.s.m.*	*Days*	*C.s.m.*
		URBAN					
Second River, N. J.	11.6	2	—	98	136	6	16
Saddle River, N. J.	54.6	34	32	33	25	4	15
		FORESTED					
Middle Branch Westfield River, Mass.	52.6	93	7	—	89	8	19
West Branch Westfield River, Mass.	93.7	94	6	—	70	8	19
Naugatuck River, Conn.	71.9	77	19	4	83	9	16
Leadmine Brook, Conn.	24.0	86	14	—	81	9	17

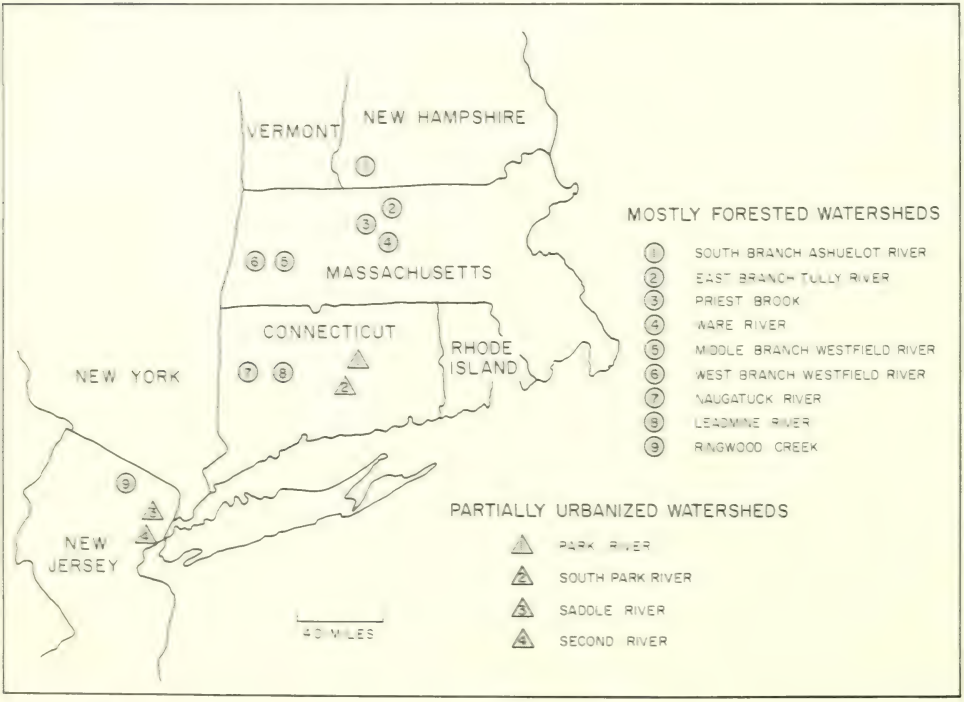
Table 4.—*Percent runoff, flow intervals, and hydrologic responses, 1940-57*

Watershed	Area	Land use			Percent of precipitation to runoff		High-flow interval		Low-flow interval		Hydrologic response
		Forest	Open	Urban	Annual	Summer	25%	50%	1%	5%	
	Square miles	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Days*	*Days*	*Days*	*Days*	*Ratio*
					URBAN						
Second River, N. J.	11.6	2	—	98	45	44	51	140	13	40	0.187
Park River, Conn.	74.0	38	31	27	51	29	34	102	18	62	.104
South Branch Park River, Conn.	40.6	48	13	34	55	33	40	112	14	51	.106
Saddle River, N. J.	54.6	34	32	33	55	36	46	120	16	53	.078
Mean	—	—	—	—	52	36	43	118	15	52	0.119
					FORESTED						
Ware River, Mass.	96.8	90	8	—	57	23	33	90	34	79	0.061
South Branch Asheulot River, N. H.	36.0	91	8	—	50	14	25	76	36	72	.085
Priest Brook, Mass.	19.4	91	8	—	57	16	26	81	38	80	.042
East Branch Tully River, Mass.	50.4	92	7	—	48	16	28	79	44	82	.053
Middle Branch Westfield River, Mass.	52.6	93	7	—	53	17	24	79	42	93	.096
West Branch Westfield River, Mass.	93.7	94	6	—	55	14	26	81	40	89	.101
Ringwood Creek, N. J.	19.1	93	3	—	53	23	30	96	46	86	.057
Naugatuck River, Conn.	71.9	77	19	4	61	32	30	89	22	78	.100
Leadmine Brook, Conn.	24.0	86	14	—	60	26	29	89	51	92	.098
Mean	—	—	—	—	55	20	28	84	29	83	0.077

Peak discharges from the urban watersheds bracket the peak flows from the forested ones, table 3. Maximum mean daily discharges and their mean number per year are greater from the forested watersheds.

Urbanization may not necessarily result in increased peak discharges from a watershed because these events are influenced not only by the areal extent of urbanization but also by the location of the urbanized area in respect to the entire basin. For example, the urbanized area of Saddle River in New Jersey is concentrated at the lower end of the basin. Peak flows from this area probably run off much more rapidly than before urbanization. Consequently, even though the peak discharges from these small down-basin urbanized areas may be higher than before, they are discharged from the basin more rapidly; and they are at a lower stage of regression before the main peak from the larger, slower-draining,

Figure 3.—Location of partially urbanized and mostly forested watersheds.



non-urbanized upper basin reaches the lower end. Hence the net result of urbanizing the lower end of a basin can result in a dispersion of desynchronization of storm peaks from the urban and non-urban areas, and a general reduction in size of the momentary peaks from the entire basin.[2]

For parameters other than maximum discharges, the percentage of summer precipitation that appears as runoff is considerably greater in the urban watersheds than on the forested watershed, (table 4). It took, on the average, 15 and 34 days longer to discharge 25 and 50 percent of the annual runoff from the urban watersheds than from the forested watersheds—or, put another way, the high flows were lower. Conversely, low flows during the growing season were higher, requiring fewer days to discharge 1 and 5 percent of the annual flow. The higher concentration of flow and the distinct difference in streamflow timing between forested and partially urbanized watersheds are further illustrated in figure 4. Finally, about 12 percent of the precipitation appears as storm-flow from urban areas and about 8 percent from forested.

In sum, high flows, except certain momentary peaks, tend to be greater from the forested watersheds, and low flows lower than from the urban watersheds. The mean peak discharge of 136 c.s.m. from Second River in New Jersey and the greater runoff from summer rainfall attest, presumably, to the efficiency with which paved surfaces deliver runoff to the channel and the lesser opportunity for evapotranspiration. Greater evapotranspiration from the forested areas during the growing season and higher rates of infiltration permit greater storage of summer rainfall and consequently less runoff; thereby more days are required to discharge the 1 and 5 percent of the annual runoff designated as low flow.

The greater high flows from the more northerly forested watersheds (fig. 3) are largely a winter phenomenon; and in part they can be due to the melt of accumulated snow under the influence

[2] This possible explanation for the low mean momentary peak of the Saddle River was suggested by John E. McCall, District Chief, U. S. Geological Survey, Trenton, N. J., in a personal communication dated 7 January 1969.

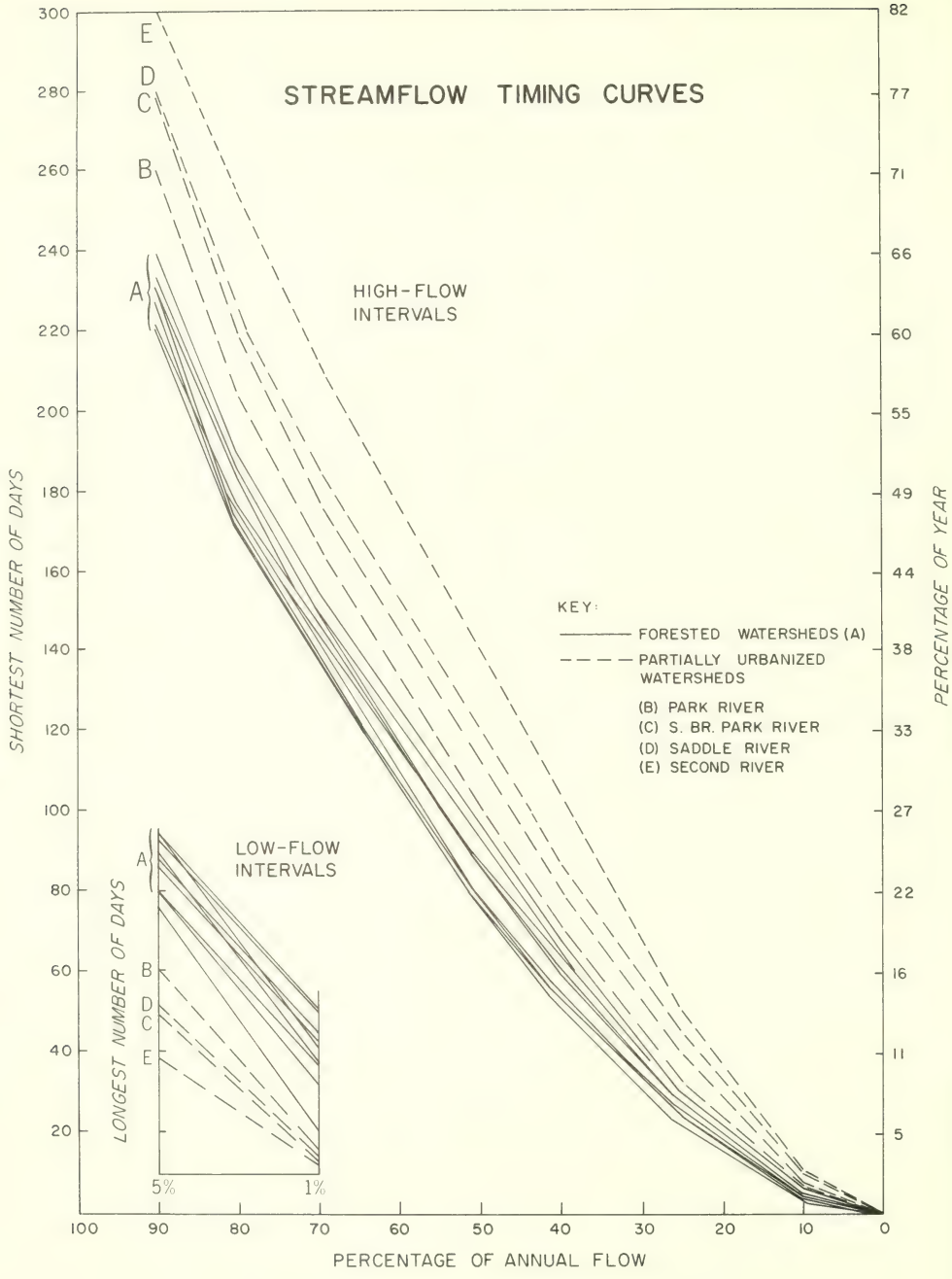


Figure 4.—Streamflow-timing curves for forested and partially urbanized watersheds in southern New England.

of winter and early spring thaws. Satterlund and Eschner *(1965)* have shown that rapid melting of accumulated snow under forest stands shortens and concentrates the high-flow period. Under urban conditions, the unshaded snow melts sooner and does not accumulate to the extent it does in forest stands; also, in metropolitan areas some snow on the streets is carted to the river by truck or is melted by salts and soot.

Further, as noted in an earlier study *(Lull and Sopper 1966),* the greater precipitation, steep slopes, and shallow soils of forested watersheds tend to produce greater runoff than can be expected from the lower-lying, less precipitous, deep soils of urban watersheds. The average elevation of the gaging stations of the nine forested watersheds was 521 feet, and for the four urban stations it was 36 feet also, the mean difference in elevations between highest and lowest points was 1,357 feet for the forested and 759 feet for the urban.

Thus, examination of streamflow records of progressively urbanized watersheds, and the comparison of streamflow from partly urbanized watersheds with that from largely forested watersheds, do not indicate the large difference in flows that might be expected theoretically from previous considerations. This may be due principally to the fact that most of the watersheds considered were only partially urbanized, and any urban effects are probably masked by discharge from the substantial non-urban areas.

CONCLUSIONS

In terms of hydrologic processes, urbanization of forested watersheds would tend to reduce interception, infiltration, soil-moisture storage, and evapotranspiration, and to increase overland flow and runoff. Several studies of peak flows have shown that they may be increased by 1.2 to 5 times over peaks from rural conditions. During development and construction in suburban areas, sedimentation may be increased greatly; and even after construction, sedimentation in these areas may be 5 to 10 times that from protected forested watersheds.

Urbanization effects on potential evapotranspiration and runoff were indicated from simulated applications of various proportions of impervious surfaces on a forested watershed. Annual potential evapotranspiration was reduced an estimated 19, 38, and 59 percent by 25-, 50-, and 75-percent impervious cover, and annual runoff was increased 15, 29, and 41 percent, respectively.

Thirty-year records of streamflow from three progressively urbanized watersheds showed increasing trends in maximum annual peak flows, hydrologic responses, and annual runoff. Maximum daily discharges from watersheds partially urbanized tended to be less both in magnitude and number than the discharges from largely forested watersheds. In addition, the percentage of precipitation that appeared as summer runoff was greater, high-flow intervals were longer, low-flow intervals were shorter, and hydrologic responses were greater from the partially urbanized areas.

We may conclude that urbanization of forested watersheds can have profound effects on hydrologic processes when they are considered individually; and, theoretically, urbanization can greatly increase runoff and peak flows. However, comparisons of actual streamflow records of partially urbanized watersheds with those from forested watersheds less than 100 square miles in area suggest that the effects of urbanization will appear principally in the greater percentage of rainfall that appears as summer runoff and in higher low flows during the summer-fall season.

Our results were inconclusive with respect to high flows during the winter-spring season, at least partly because of latitude and elevation differences between the forested and urbanized watersheds selected for this study.

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A Look at the MINE-TIMBER MARKET in the Appalachian Bituminous Coal Region

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

THE AUTHOR

ROBERT G. KNUTSON, received his bachelor of science degree in forest management from the University of Minnesota in 1957. He joined the USDA Forest Service's Lakes States Forest Experiment Station (now North Central Forest Experiment Station) that same year. While at that Station he collected and analyzed timber-inventory data, particularly timber-cut data. In 1967 he joined the staff of the Northeastern Forest Experiment Station's Forest Products Marketing Laboratory at Princeton, West Virginia.

A Look at the MINE-TIMBER MARKET in the Appalachian Bituminous Coal Region

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Figure 1.—The Appalachian bituminous coal region.

THE QUESTIONS

DO COAL MINE OPERATORS use many mine timbers? What are the specifications for mine timbers? Does producing mine timbers differ from producing other sawmill products? These are typical of the questions that sawmill operators in the Appalachians ask about the mine-timber market.

At first glance it seems strange that they would ask such questions. After all, the mine-timber market is a traditional outlet for wood products in the Appalachians, and it would seem that all sawmill operators in the region would be familiar with the market. But this is not the case. Sawmill operators, unless they sell mine timbers, know little about the market Even those who sell mine timbers know little about the coal industry's current and potential need for mine timbers, because they generally supply only one or two mines.

This report was prepared to answer some of the questions that sawmill operators have about the mine-timber business in the Appalachian coal region (fig. 1).

HOW WOOD IS USED IN MINING

Wood is used in underground coal mines primarily to support the roof in the opened coal seam. For this purpose, round, split, and sawed timbers are used. Collectively these timbers are referred to as "mine materials", "timbers", or "mine timbers". Generally, round and split timbers are used for upright supports. Sawed timbers are used primarily for horizontal supports, mainly headers and half-headers. Sawed wood is also used for mine ties, floor

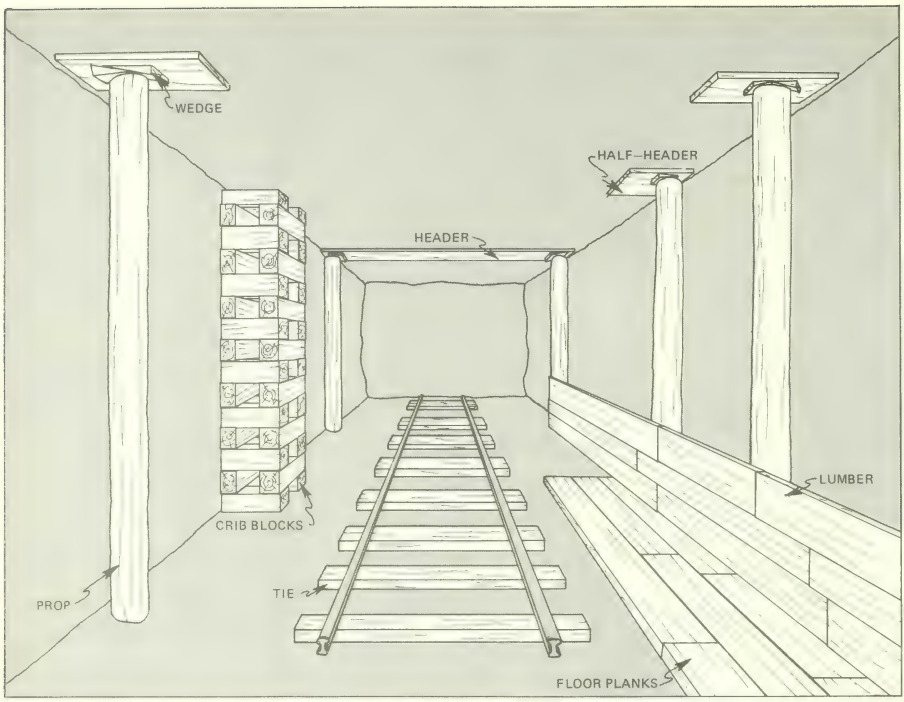


Figure 2.—Examples of timbers used in the underground bituminous coal-mining industry.

planking, wedges, crib blocks, construction and repair, and a number of minor uses (fig. 2).

As coal is extracted from the coal seam, roof support timbers are set and, depending on the mine or area in the mine, mine ties are laid, flooring is extended, and other uses are made of wood. Thus there is a direct relationship between the tonnage of coal mined and the volume of wood used.

Even though two coal companies produce the same tonnage of coal, their wood requirements may differ. The volume of wood used varies with the thickness of the coal seam, the nature of the roof and floor, the type of machinery used, other types of roof supports used, and the purity of the coal. For example, a mine with a rail system for hauling coal to the mine opening might use wooden mine ties. A mine with a conveyor system for hauling coal would not use mine ties.

PRODUCING AND SELLING MINE TIMBERS

Mine-Timber Market

Producing mine timbers for the coal industry differs somewhat from producing sawed wood products for other wood-using industries. Four of the more important differences are:

1. The coal industry does not have industry-wide specifications for mine timbers. Although all operators of underground coal mines use wood in mining coal, each mine operator determines his own timber specifications.
2. The mine-timber market is a first-hand contact type of market. Generally only the sawmill operator and the coal mine operator or his purchasing agent are involved in the buying and selling of mine timbers. Some of the larger coal companies purchase timbers through a timber broker, but this is the exception.
3. The working agreement between sawmill and coal-mine operators is on a long-term basis. Once an agreement to supply timbers is established, the agreement usually continues until one or the other quits operating for some reason. The agreement continues even though mine operators may be able to obtain timbers at lower prices elsewhere. Mine operators seldom change suppliers for a price advantage alone. If their present timber supplier is reliable, they do not want to jeopardize their mining operations because of a probable small savings on mine timbers. An advantage to this, of course, is that the sawmill operator is assured of a long-term market.
4. As coal is mined on a regular basis, so are mine timbers needed on a regular basis. To the sawmill operator, this means that green timbers can be sold, little storage space is required at the mill, and inventory turnover is rapid. Above all, it means that the mine-timber market is a steady market.

Mine-Timber Specifications

Coal-mine operators require timbers to be: (1) suitable for the intended use in the mine, (2) manufactured to their standards, and (3) structurally sound.

Most mine timbers are used to support the mine roof. Therefore strength qualities are most important in mine timbers. Other qualities such as durability, elasticity, and ease of construction are also important. Fortunately, in the Appalachians there is an abundance of species suitable for all types of mine timbers.

Mine timbers must be sawed to fit the dimensions of the working area in the mine. This is the major reason why mine-timber sizes cannot be standardized industry-wide. The dimensions of the working area are dictated largely by the height of the coal seam, which varies from mine to mine, and also varies within the same mine. Therefore mine timbers must be sawed to fit the conditions in the particular mine or area in the mine. Table 1 shows common sizes for mine timbers.

Many coal companies use drilled headers and half-headers. Roof bolts inserted through these timbers are fastened in the roof strata. In this method, a hole is drilled in the strata and a steel bolt several feet long is inserted in the hole. The bolt has 6 inches or more of threads at the end, with a metal expander attached, which gives a firm grip on the hole as the bolt is tightened. This binds several strata together, effectively forming a compound beam.

Some coal companies use treated timbers. Mine ties are often treated, but which timbers are treated and how many timbers are treated depends primarily on the expected life of the mine.

Another general requirement for mine timbers is that they must be structurally sound. No regard is paid to the decorative

Table 1.—*Dimensions of sawed mine timbers*[1]

Type	Thickness	Width	Length
	Inches	*Inches*	*Feet*
Wedges	1/8-1	4	1
Crib blocks	5	5	2 1/2
Half-headers	2	8	1 1/2
Headers	3	8	14
Ties	5	7	6
Miscellaneous	1	10	12

[1] Most of the round and split timbers are 36 to 70 inches long. Average length is about 53 inches, and average diameter is about 6 inches.

qualities of wood such as the furniture, flooring, and millwork markets demand. This means that sound logs and cants that will not yield lumber suitable for decorative purposes can be sawed for mine timbers.

Equipment Needed

The basic sawmill equipment required to produce mine timbers includes a headsaw, edger, trimmer, and wedgesaw, along with the necessary roller conveyors, refuse conveyors, and other auxiliary equipment. In addition, a drill press will be needed if drilled headers and half-headers are to be produced. Treating equipment will be required if treated material is to be produced.

Special attention needs to be given to the output end of the sawmill for efficient production, handling, and storage of mine timbers. Because of the large number and variety of sizes of mine timbers produced, a large sorting and storage dock is required to provide immediate access to each of the different items.

CURRENT USE OF WOOD IN MINES

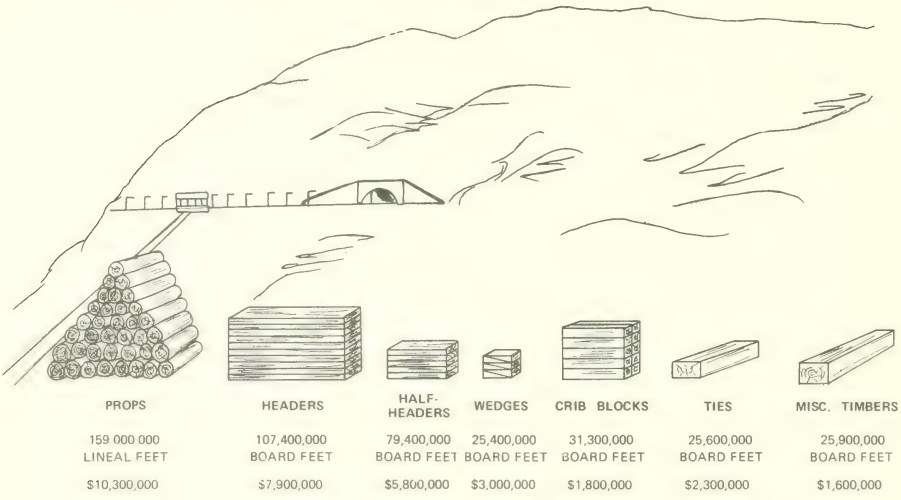
Mine-Timber Volumes

In 1967, an average of 1.0046 board feet of sawed timbers and 0.5420 lineal foot of round and split timbers were used for every ton of bituminous coal mined. In that year, approximately 294 million tons of bituminous coal were mined from underground mines in the Appalachian region. To produce this tonnage, an estimated 295 million board feet of sawed timbers and 159 million lineal feet of round and split timbers were used.

Mine-Timber Prices

Prices paid for mine timbers by a particular coal company vary according to such factors as delivery distance, timber species, size and quality, and whether the timbers are drilled, treated, or both drilled and treated. Average prices paid in 1967 for timbers delivered to the mines was $0.065 per lineal foot for round and split timbers, and $76 per thousand board feet for sawed timbers.

Figure 3.—Volume and value of wood used in underground bituminous coal mines in the Appalachian coal region in 1967.



The average price per thousand board feet for each type of sawed mine timber delivered to the mines was:

Wedges	$119
Ties	90
Headers	74
Half-headers	73
Miscellaneous timber	60
Crib blocks	58

Figure 3 shows the estimated volume and value of each type of timber used by the Appalachian underground bituminous coal mining industry in 1967.

Species

A number of species are used for mine timbers. Each mine operator has his preference, but generally he uses the species available in the locality of his mine. An estimated 55 percent of the sawed timber volume is oak, primarily red oak; 15 percent hickory; 15 percent yellow-poplar, basswood, and cucumber; 6 percent beech; 5 percent pine and hemlock; and 4 percent miscellaneous hardwoods. The volume of round and split timbers consists mainly of oak, hickory, and beech.

OUTLOOK FOR THE MINE-TIMBER MARKET

Future wood requirements of the mining industry will depend on the demand for coal and on the need for wood in coal mining. The demand for coal is keyed to the demand of the industrial, export, coking, and electric utility markets. The need for wood will depend primarily on how effectively wood can compete with other products.

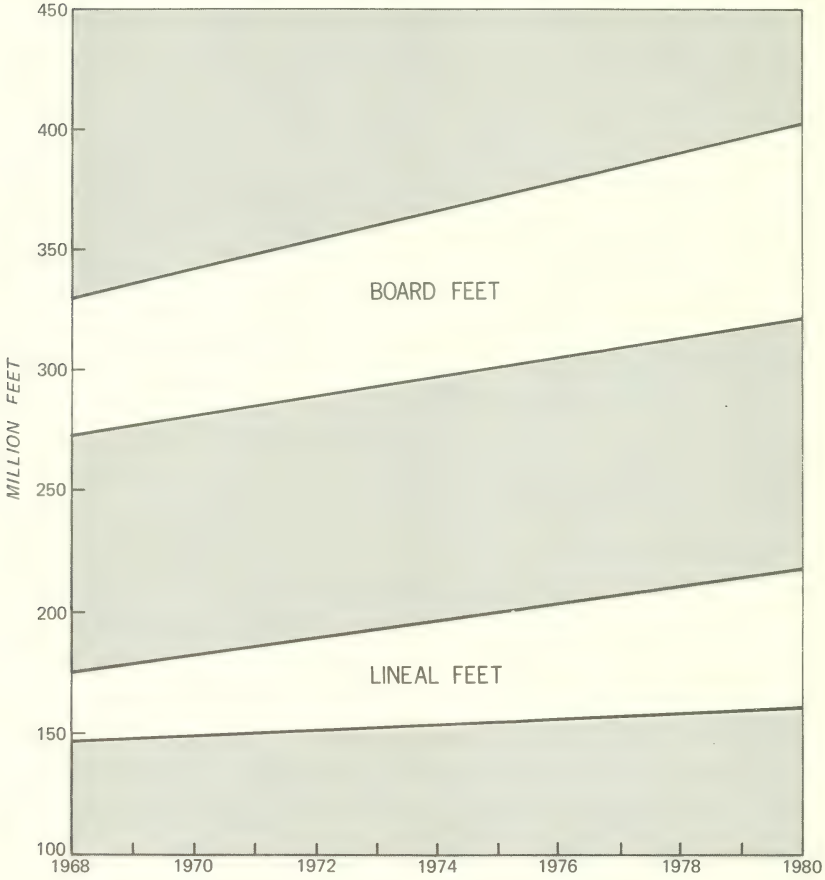
In recent years the trend in coal production has been upward. This trend is projected to continue; and it reflects the expected demand for coal by the major markets, especially the electric utility market. Electric utilities annually consume 50 to 60 percent of the Appalachian coal production. As electric utilities have expanded their production facilities in recent years—and continued expansion is expected—this market should continue strong for a number of years. The other major markets for coal are expected to maintain or gradually increase their demand for coal.

Indications are that coal production will continue to increase in future years. The volume of wood used in mining will also tend to increase, provided wood can continue to compete with substitute products. Although products such as roof bolts will continue to replace some wood in the mines, especially round and split timbers, many coal mine operators say they will use wood at about the same rate as they do now. This, together with the availability of timber in the Appalachian coal region, the relatively low cost of mine timbers, and the adaptability of wood, suggests a strong demand for wood in the future.

Assuming that underground coal production will rise at a steady rate until 1980, when 400 million tons of coal are expected to be produced underground in the Appalachian region, we can project an estimate of how much wood will be needed (fig. 4). These projections on wood use are based on the expectation that the wood use per ton of coal mined will remain the same or will decline somewhat.

Coal mine operators now have little difficulty in obtaining the timbers they need. However, this situation may change as the structure of the sawmill industry in the Appalachians changes.

Figure 4.—The projected range for the volume of mine timbers that will be needed in future underground bituminous coal mining in the Appalachian coal region.



Because of the geographic closeness of sawmills and coal mines in the Appalachians, it is easy for operators of coal mines and sawmills to discuss mine-timber prices, specifications, problems, and so forth. But there is a gradual reduction of sawmills in the Appalachians. With the reduction in number of mills, there is likely to be a growing distance between the mines and sawmills. A communication gap could develop, and this market for wood could be gradually lost. Therefore it is important that sawmill operators keep the needs of nearby coal mines in mind when considering the various potential markets for their products.

USEFUL REFERENCES

For the sawmill operator who wants to know more about the economics of producing timbers, two current publications are available:

Church, Thomas W., Jr., and L. D. Garrett.
Should hardwood lumber manufacturers consider crosstie production? Submitted for publication in S. Lumberman.

Garrett, Lawrence D.
Economic implications of manufacturing sawed ties and timbers. USDA Forest Serv. Res. Paper NE-148. 24 pp., illus. NE. Forest Exp. Sta., Upper Darby, Pa. 1969.

Although these publications do not deal directly with producing mine timbers, the same type of reasoning can be used in making a decision about producing mine timbers. These publications can be obtained by writing to the USDA Forest Service, Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

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Thanks are due the coal-mine operators for their co-operation in supplying the information used in compiling this report. James E. McElroy, who formerly served with the Northeastern Station, initiated the study. Kenneth W. Whitenack, mathematician, assisted in the collection and compilation of the data.

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by Lawrence D. Garrett

Economic Implications
of manufacturing sawed ties and timbers

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The Author

LAWRENCE D. GARRETT received his bachelor of science degree in forestry from Southern Illinois University in 1963. After an appointment to the Black Hills National Forest, Custer, S. Dakota, he went to Michigan State University, East Lansing, Mich., where in 1965 he received a master of science degree in forest economics. Since 1965 he has worked as a research forester at the Forest Products Marketing Laboratory of the Northeastern Forest Experiment Station at Princeton, W.Va.

Economic Implications
of manufacturing sawed ties and timbers

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SAWED TIMBERS: A PROFITABLE PRODUCT

MOST HARDWOOD lumbermen recognize inherent advantages in manufacturing sawed timbers: higher overrun from reduced kerf loss; reduced sawing time and milling cost per unit of volume output; quicker return from the sale of green timbers; and no degrade loss from yard seasoning. They also see the disadvantages: lower prices than for most lumber grades; limited and fluctuating markets; and restricted suitability of logs for timber manufacture.

Many sawmill operators who have never cut timbers are reluctant to venture into this field. Other lumbermen have had an unsatisfactory experience in producing sawed timbers and have vowed never to enter this market again. Yet the extra income from sawing timbers along with standard lumber should entice some progressive mill managers to seek these valuable but somewhat erratic markets.

The purpose of this paper is to discuss those factors that affect the profitability of manufacturing timbers and show that the combined manufacture of both lumber and timbers will provide a greater daily income than the manufacture of lumber alone.

STUDY OBJECTIVES

The study was undertaken to investigate the profitability of manufacturing sawed timbers and to learn if sawing timbers and lumber would be more lucrative than sawing only lumber. We sought answers to four questions:

- What grades of lumber are enclosed within timbers sawed from each grade of factory logs?

- What operational and economic factors control the feasibility of sawed timber manufacture?
- If producing timbers and lumber from each log is more profitable than producing lumber only, what species and grades of logs provide the greatest financial gain when hearts are sawed into timbers of different sizes?
- How do management and marketing problems affect the profitability of sawing ties and timbers?

METHODS

The initial sawing of a log in a sawmill yields either lumber or lumber plus one or more timbers. Because the sawyer can cut either all lumber or lumber plus a timber, two questions arise: Which practice provides the greater profit to the millowner? And what generates this extra profit?

To effectively compare these two practices, approximately 700 randomly selected sample logs were sawed into standard lumber thickness. Then this lumber was graphically arranged to simulate its original position within the log. Finally, the board components of each log were restructured to simulate various sizes of timbers in the heart. Observed lumber thicknesses remained in residual peripheral sections. In the simulated sawing of the graphically reconstituted logs, no new saw lines were developed. The borders of the superimposed timbers followed the saw lines actually made during the initial log breakdown.

This simulation allowed us to develop accurate costs and production times for the two sawing methods. We computed the additional volume yields from sawed timber manufacture, the extra log volume required, and the net dollar yield from standard lumber and timbers of different sizes. This permitted us to show what combinations of species, log grades, and sawed timber sizes resulted in the largest increase in dollar income per hour to the millowners.

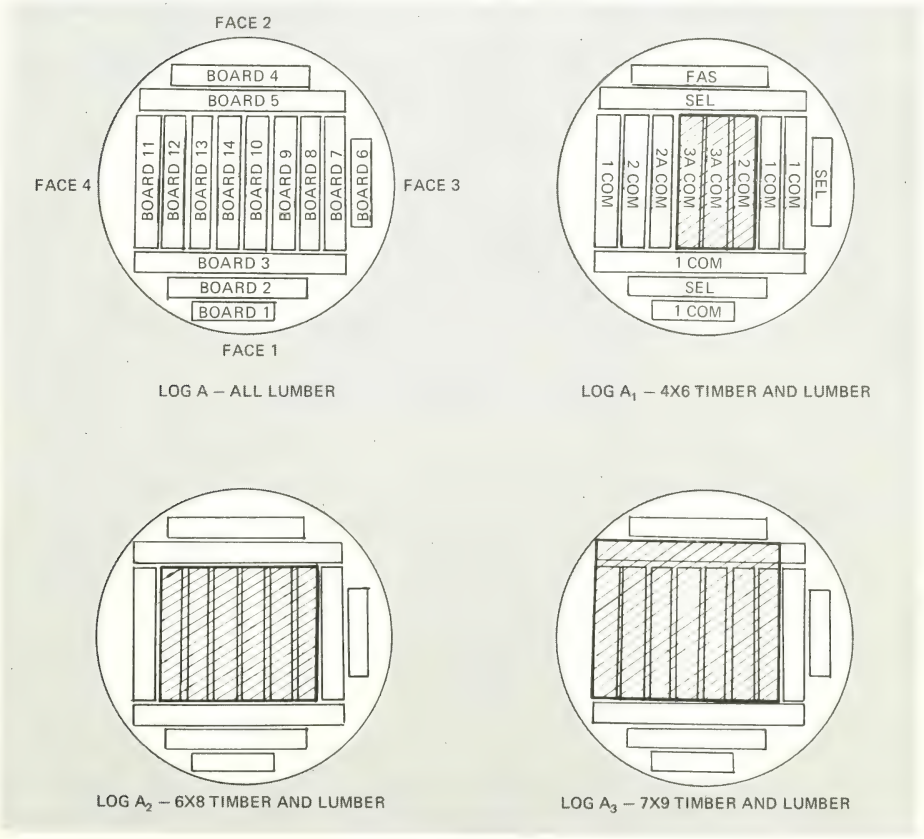
Data used in this study were collected at three West Virginia circular mills cutting 4.5 to 5.5 thousand board feet per day.

Log costs, production costs, and prices received for manufactured products were essentially the same at the three mills. Therefore one set of cost and price data was used to represent all three mills (tables 7 to 10).[1]

The primary sawing method used by the three mills is illustrated by log A in figure 1. The order in which boards were sawed from the sample logs is represented by the sequential face and board numbers. The sawing method incorporated grade-sawing techniques in peripheral high-value sections and production sawing in the low-quality heart.

[1] All tables are in the appendix.

Figure 1.—Product alternatives cut from sample logs.



Four species groups and three log-grade classes provided the basic data. Red oak, white oak, and hickory were selected because they are used extensively for manufacture of ties and timbers. Hard maple was included to determine if sawed timbers could be produced economically from a high-value species. Log quality was measured by the U.S.D.A. Forest Service log-grading system for factory logs.[2] Tie-and-timber or local-use logs were classified in the factory grade 3 class. Approximately 50 logs were in each species group and log-grade class.

620 logs were graded and sawed into 1-inch lumber. Some 5/4-inch boards were cut when the sawyer thought this thickness would be best. All lumber was graded by National Hardwood Lumber Association inspectors. The restructured full-length 4-by-6-, 6-by-8-, and 7-by-9-inch timbers were not graded per se; however, the exposed face of each board sawed from each log was graded either acceptable or not acceptable for timber production. These timbers were graphically superimposed on the lumber actually sawed from each sample log. The placement of these superimposed timbers was controlled by the position of the pith or center of each log. The reason for using the pith or log center as criterion for timber location is due to the profound concentration of low-quality lumber in and around the pith.

ANALYTICAL PROCEDURES

To properly identify the factors influencing cost and value changes when timbers are sawed, and to accurately assess the profitability of sawing timbers, we used two analyses.

In the first analysis (I) we imposed the optimum condition that all logs studied could be manufactured into timbers. This control permitted us to evaluate the effects of species and log-grade differences and ultimately to define the logs most suited economically for production of timbers.

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[2] Ostrander, M. D., and others. A GUIDE TO HARDWOOD LOG GRADING (REVISED). U.S.D.A. Forest Serv. NE. Forest Exp. Sta., 50 pp., illus. Upper Darby, Pa. 1965.

In the second analysis (II) we studied 100 mill-run red oak logs to determine the expected economic effectiveness of producing timbers under actual conditions. Many of the logs were not suited for the manufacture of timbers because of the individual or combined effect of small diameter, center rot, sweep, and end shape. By studying the production of timbers under actual operating conditions, we were able to determine the effects of physical log suitability, price changes, and management control on the profitability of sawing timbers.

RESULTS AND DISCUSSION

Our investigation revealed that, under the price and cost situations prevailing at the mills studied: (1) If sawed timbers are cut from the hearts of physically suitable hardwood logs, the combined profit from lumber and timber will be greater than if these same logs were sawed entirely into grade lumber. This prevails even when large timbers are sawed from high-grade logs. (2) If markets are available, a millowner should cut a tie or timber from *every* log physically suited for this product. If markets are restricted, tie and timber production should be confined to the lower grade logs. These statements are based on consistent relationships between the manufacture of timbers and lumber.

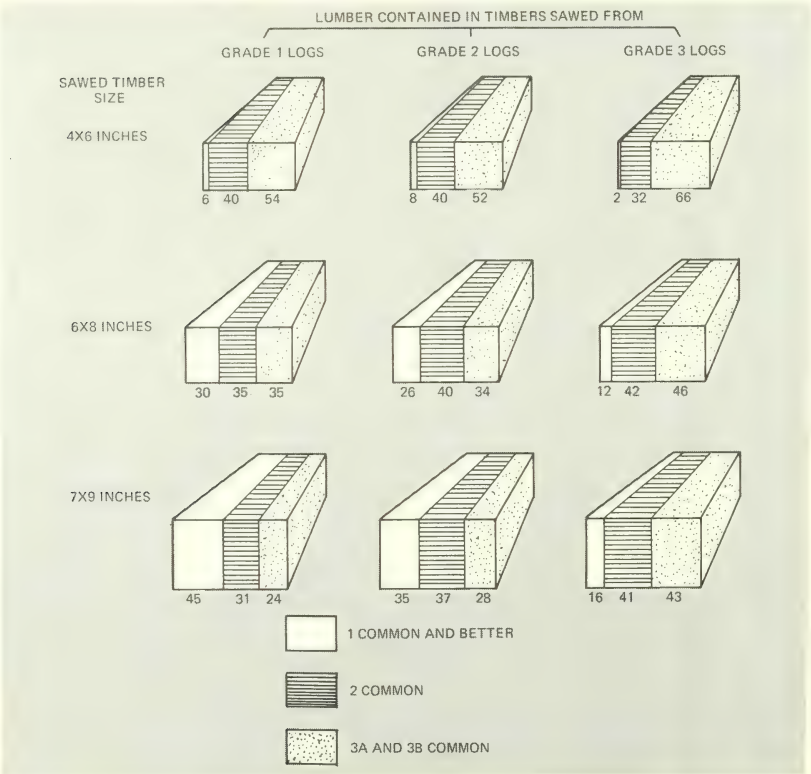
Results are presented by log grade rather than by log diameter because grade was felt to be a more meaningful control factor for mill managers. Although diameter represents a universally understood variable, it alone does not show value relationships that are so important in the alternatives of lumber versus timbers.

Log diameter does control maximum timber size. But the decision to saw a timber from a log that is big enough, straight enough, and sound enough does not depend upon diameter. Published information already shows the timber dimensions that can be sawed from logs of different sizes. So the ultimate decision to saw a timber should not rest upon log diameter but upon the value of the lumber contained in the timber compared to

the selling price of the timber itself. Lumber values must be considered. And lumber values differ substantially within similar size timbers sawed from different log grades. Therefore log grade becomes a reasonable criterion for resolving the question of whether to saw lumber or a timber-lumber mix.

Because sawed timbers allow an unlimited number of defects that do not reduce strength, sawmill operators aim to cut these timbers from heart portions where grade defects are concentrated. Nevertheless, larger timbers often contain high-value lumber that may be worth more than the sawed timber. Before we assess the economics of sawed timber production, we must establish the lumber grade composition of different size timbers.

Figure 2.—Proportionate distribution of lumber grades in different size timbers sawed from three log grades—all species combined.



Timbers sawed from low-quality logs contain at least 75 percent 2 and 3 Common lumber regardless of timber size (table 1). However, the percentage of high-quality lumber in sawed timbers increases as log quality rises and timber size expands. For example, 4-by-6-inch timbers sawed from grade 3 logs have an expected yield of only 2 percent 1 Common and Better material, whereas 7-by-9-inch timbers sawed from grade 1 logs are composed of 45 percent 1 Common and Better lumber (figure 2).

Although grade-lumber yield from sawed timbers is important, it is not the only factor affecting the economics of producing timbers. Several changes occur when timbers are manufactured along with lumber, and each change affects the profitability of the venture.

ANALYSIS I: THE OPTIMUM RETURN

Six factors — overrun, grade yield, the difference between lumber and sawed timber prices, conversion time, log costs, and production costs—determine the profitability of sawing timbers. Some of these factors complement one another; for example, reduced conversion time lowers production cost per unit of volume sawed. However, some factors oppose each other; for example, the cost reduction from greater hourly output is blunted by the increased costs for the additional raw material required.

The interrelationships among these six factors and their joint effect upon net hourly income are illustrated in table 2. These tabular data contrast the economic merits of sawing either lumber or lumber plus 7-by-9-inch timbers from high-quality maple logs and low-quality hickory logs.

Overrun

Sawing timbers and lumber provides a greater overrun than sawing lumber only. Losses in salable volume from kerf and allowances for shrinkage and surfacing are entirely eliminated in the sawed-timber portion of a log. Therefore more salable volume is recovered. Because low-quality logs are generally smal-

ler than high-quality logs, a greater portion of small low-quality logs are sawed into timbers. Consequently the percent overrun is greater from these logs.

The additional overrun from sawing 7-by-9-inch timbers from hickory and maple sample logs was 297 and 216 board feet, respectively (table 2). Although the volume increase from sawed timbers is higher in the small low-quality hickory logs, an appreciable increase in overrun occurred in both log groups.

Lumber Quality and Price

Although sawed timbers provide a greater overrun, the total product value of this lumber-timber mix from a given group of logs may be less than the income obtained when only lumber is sawed. Timbers cut from high-value logs will contain some high-quality lumber that commands a high market price. With high lumber prices, the enclosed lumber could be worth more than the entire timber even when increased overrun is considered.

For example, in table 2, the maple lumber enclosed in the timbers was worth $100.90, whereas the timbers were worth only $65.76. Thus high-value logs will usually show a decrease in total product value when timbers are sawed from them. In this example, the reduction was $35.14. Conversely, low-value logs usually show an increase in total product value from sawing both timbers and lumber. The gain for the low-grade hickory logs in table 2 amounted to $22.64 ($90.05 – $67.41).

Conversion Time

Conversion time per thousand board feet of output should always decline when timbers are sawed. Sawed-timber manufacture eliminates the time required to saw up the center portion of a log. As a result, more volume can be produced in less time.

The largest reduction in sawing time occurs in the small low-quality logs. Low-quality logs normally have smaller diameters than high-quality logs. If timbers of equal size were cut from both groups, a greater portion of the volume in the low-quality logs would be sawed into timbers. Thus a greater percent

of total conversion time would be eliminated by sawing timbers from the poorer logs.

This principle needs to be illustrated for greater emphasis. Figures in table 2 show that 2.45 hours were needed to saw 1,595 board feet of lumber from large grade 1 maple logs and 2.59 hours were needed to saw 1,552 board feet of lumber from smaller grade 3 hickory logs. Thus hourly lumber output was 651 board feet for maple and 600 board feet for hickory. This relationship is plausible because the hickory logs were smaller, and the wood was more difficult to saw.

Now, when both lumber and 7-by-9-inch timbers were sawed from the large maple logs, hourly output totalled *875* board feet (1,811/2.07). The hourly output of lumber plus 7-by-9-inch timbers from the smaller hickory logs jumped to *943* board feet (1,849/1.96). Thus the increased hourly yield from sawing timbers from smaller low-grade hickory logs was *343* board feet, whereas the increased hourly yield from sawing timbers from the larger high-grade maple was only *224* board feet. This comparison shows why the smaller low-grade logs require less conversion time.

Conversion time per board-foot unit produced is a critical factor controlling the size of profits when sawing both lumber and timbers because: (1) it is easily altered; and (2) it is one of the major determinants of hourly product value. To effect a decrease in conversion time per thousand board feet, a millowner only needs to increase the production of timbers. The immediate result is a marked increase in the volume of products manufactured hourly. In all the species groups studied, dollar yields from this increased volume more than offset the lower prices received from timbers. Therefore, *hourly product value* was always greater when timbers were produced.

For example, the total product value of the lumber sawed from the group of maple logs (table 2) was $279.51 compared to the total product value of $263.30 for both lumber and timbers. However, on the basis of *hourly* product value, which reflects the time required to saw, the lumber-timber mix yielded $13.11 more per hour in salable products. The higher hourly

product value for the lumber-timber mix resulted from a 16 percent (0.38 ÷ 2.45) reduction in conversion time when timbers were sawed. In low-quality logs, like those in the grade 3 hickory group, total product value was greater when timbers were produced because of overrun alone. Therefore the $30.21 increase in hourly product value obtained from low-quality hickory logs was considerably larger than the increase from high-quality maple logs.

Log Costs

Costs incurred in producing both lumber and timbers can be designated as either material input costs (logs) or production costs.[3] Hourly log costs should always increase when timbers are sawed because the reduction in individual log sawing time means that more logs can be sawed per hour.

When a millowner saws both timbers and lumber, his increase in hourly log costs will be greater for high-quality logs than for low-quality logs. High-quality logs of a given species may cost $20 to $30 per thousand board feet more than an equal volume of low-quality logs (table 9). Also, a group of low-quality logs will yield a greater overrun because the average scaling diameter is smaller. Therefore the combined effects of overrun and purchase price favor sawed-timber manufacture from the smaller low-quality logs. For example, 7-by-9-inch timbers sawed from grade 1 maple logs increased log costs $7.24 per hour, whereas the same size timbers sawed from grade 3 hickory logs increased log costs only $2.42 per hour (table 2). Yet total salable volume from the hickory logs was 81 board feet greater than the total salable volume from maple logs; and this extra output from hickory required about 7 minutes less sawing time.

Production Costs

Sawed timber manufacture usually reduces production costs because grading, stacking, and loading sawed timbers normally require less manpower, machinery, and time compared to an

[3] Includes costs incurred in milling, stacking, drying, and loading for shipment.

equal volume of lumber. Timbers are normally graded at the expense of the buyer and do not need to be stacked for drying. Because timbers are sold green, inventory costs per unit of sawmill output are lower for the timber-lumber mix than for lumber alone. Consequently, a given volume of timbers can be produced at a lower cost than an equal volume of lumber.

With the increased output of sawed timbers, production costs per unit of volume should decrease because an operator can produce more volume with the same crew and equipment. However, mill size dictates the extent to which hourly production costs can be reduced. A small millowner often uses only one lift truck to handle both logs and lumber. He also employs fewer men to stack and handle this lumber. In this kind of operation, significant labor or equipment costs probably could not be eliminated even though inventory costs could be reduced. For example, at the small mills used in this study, hourly production costs did not differ between milling timbers and lumber and milling lumber only (table 2).

What Species and Grades of Logs Provide The Greatest Financial Gain?

Lumber value is a key factor in defining the most economically suited logs for production of timbers. Of the six factors, the value of lumber sawed into timbers had the only negative effect upon total product value: for example, total product value dropped from $279.51 to $263.30 when timbers were manufactured from the hearts of grade 1 maple logs (table 2). This reduction occurred because sawed timber prices usually range from $55 to $75 per thousand board feet, whereas prices for Common lumber grades range from $65 to $130+ per thousand board feet. To minimize or eliminate this reduction in total product value, timbers should be cut primarily from lower quality logs containing low-value lumber. These logs provide the millowner with his greatest gain when sawing timbers.

When timbers are cut from logs of the same grade but of different species, dollar gains will be greatest from those logs

that would provide the least return when sawed into lumber. In this study, grade 3 hickory logs lost $6.40 per hour if sawed into only 4/4 lumber, yet these same logs would allow an optimum return of $21.39 per hour if sawed into lumber and 7-by-9-inch timbers (table 3). Therefore, the total gain from sawed-timber manufacture would be $27.79 per hour. However, for grade 1 maple logs the total gain from lumber plus 7-by-9-inch timber manufacture would amount to only $5.87 per hour. This smaller increase for maple may be attributed to the higher value of the lumber contained within the sawed timber.

Similarly, when only one species group is considered, the lowest quality logs in that group will yield the greatest dollar gain when sawed into timbers. For example, hourly gains of $20.05, $13.87, and $9.20 accrued when 7-by-9-inch timbers were cut from red oak logs of grades 3, 2, and 1, respectively (table 3).

Log quality alone does not always provide an accurate criterion for comparing the economic merits of sawing timbers of the same size from two different species. For example, data in table 3 show that when 7-by-9-inch timbers were sawed, grade 2 hickory logs yielded a higher hourly gain—$19.56—than grade 3 maple logs—$17.99. However, because many interacting factors affect dollar yields from different groups of logs, log grade is the best indicator to use.

ANALYSIS II: EXPECTED RETURN TO SMALL MILLOWNERS

Up to this point, we have discussed the economic advantages that accrue from sawing timbers from different species and grades of logs. Now we want to consider the practical aspects. Under actual operating conditions, sawmill owners must cope with problems like physical suitability of logs for timber manufacture, fluctuating price levels, byproduct losses, and the material flow and marketing of a multiproduct output. All these factors affect sawmill profits.

Physical Suitability of Logs

Every millowner knows that all logs are not physically suited for the manufacture of timbers. A study completed at the Forest Products Marketing Laboratory[4] revealed that, as log quality decreases, the physical suitability of these logs for production of timbers also decreases (fig. 3).

Dollar gains from sawing timbers are directly related to the number of logs from which timbers are sawed. The maximum return occurs when a timber is manufactured from every log (analysis I, table 3). However, under actual operating conditions

[4] Garrett, Lawrence D. PHYSICAL SUITABILITY OF APPALACHIAN HARDWOOD SAWLOGS FOR THE MANUFACTURE OF SAWED TIMBERS. Unpublished report on file at the Forest Products Marketing Laboratory, Princeton, West Virginia. 1967.

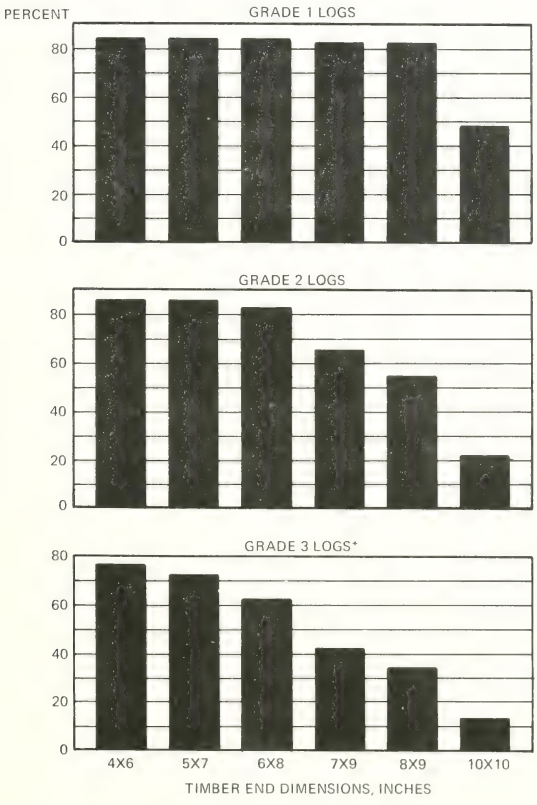


Figure 3. — Portion of sample logs suitable for the manufacture of various size timbers. Sample logs represent the mean percent of three species groups: red oaks, white oaks, and hickories. Grade 3 includes tie-and-timber and local-use grades.

many logs cannot be used for sawed timbers. For example, about two-thirds of the grade 3 red oak logs studied were suitable for producing 6-by-8-inch timbers, but only two-fifths were suitable for 7-by-9-inch timbers (table 4). Therefore sawmill operators must not expect the substantial dollar increases shown in table 3 because these data apply to optimal situations where all logs are suitable for sawed-timber production.

Even though many logs are unsatisfactory for sawed timbers, this does not make the venture unprofitable. With costs and prices reflected in this report, small mill operators can expect an additional $5 per hour from producing 4-by-6-inch red oak timbers and lumber (table 5). If they can saw 6-by-8inch timbers from about two-thirds of their red oak logs, the net increase in hourly income should range from $6 to $8. Gains from sawing 7-by-9-inch timbers should range from $7 to $10 per hour, depending upon the grades of oak logs sawed. Thus small millowners can legitimately expect daily gains of $35 to $70 by converting a portion of their lumber output into sawed timbers. Larger mills could, of course, expect a greater daily gain.

Decreased Prices for Timbers

We also found that the study mills could absorb a significant drop in the prices they received for timbers and still produce them at a greater profit than if they had sawed the same logs into lumber. For example, when prices were purposely reduced $10 per thousand board feet (price level I to II), net values dropped only $1 to $3 per hour (table 6). With an additional $10 per thousand board feet price reduction (price level II to III), hourly values dropped another $1 to $3. Therefore, even if timbers sold for $20 per thousand board feet less than their current market value, the mills could still expect a greater hourly return from a combined lumber-timber output than from lumber alone.

Management Considerations

In addition to the physical suitability of logs and the potential changes in sawed timber prices, a millowner should be aware of other problems affecting profits.

First, logs cut to specified tie-and-timber lengths may give a high proportion of short boards in packaged lumber shipments. Millowners who buck all logs to specified timber lengths will accumulate odd lengths of lumber, such as 8-foot 6-inch, 9-foot, and 11-foot boards. Lumber-grading regulations permit only 50 percent of a lumber shipment in odd lengths without incurring a price reduction. In addition, grading rules specify that FAS lumber shipments may include only 15 percent in shorts 8 and 9 feet long or else the lot is subject to penalty. Similar restrictions are imposed on other grades.

Second, sawmill operators who do not tailor log lengths to specified timber lengths may incur losses from throw-away ends of timbers that exceed commercial lengths. For example, a standard 7-by-9-inch, 8-foot 6-inch crosstie cut from a 10-foot log produces a waste block 7 by 9 by 18 inches, containing 7.8 board feet. If 50 of these blocks were discarded daily, volume losses would total 390 board feet. The value of this waste material if sold as timbers at $60 per thousand board feet would amount to $23.40.

When sawing 6-by-8-inch timbers from suitable logs, the study mills produced approximately 40 waste blocks per 8-hour shift. Because the average length of these blocks was 6 inches, daily losses amounted to 160 board feet, worth $9.60. However, this *daily* loss from waste blocks was almost balanced by the *hourly* gain achieved from sawing timbers instead of lumber.

Third, grade sawing is not always compatible with the sawing procedures best suited for timbers. When logs are sawed for maximum grade recovery, the sawyer must concentrate on the log faces that have fewer discernible surface defects. These faces are sawed deeper to permit recovery of as much clear lumber as possible. However, most railroads prefer ties with boxed hearts to reduce the likelihood of severe splitting and to permit better penetration of creosote in surrounding sapwood zones. Also, for sawed timbers, specifications on knot size are more lenient if these defects are placed within the face rather than along the edge. For grade lumber, defects should be positioned along the board edges to permit the greatest yield in high-value clear cuttings.

Thus the sawing method customarily used for lumber does not always complement the practice best suited for timbers.

Good supervision of log bucking and sawing practices should minimize the losses from short boards, over-length timbers, and miscut lumber. However, a millowner should continuously be aware of losses from inadequate supervision and management, and he should remedy them as soon as they are discovered.

CONCLUSIONS

In this report, we investigated the economic implications of manufacturing sawed ties and timbers in conjunction with factory-grade lumber. Based on the results, these conclusions appear pertinent:

- When markets for sawed timbers are available, the combined production of both lumber and timbers from physically suitable logs will give a greater dollar return than the production of lumber alone. Millowners can expect increased dollar gains from sawed timbers cut from low-, medium-, or even high-grade logs. With current price structures, the study mills received up to $70 per day more from sawed-timber manufacture. Even if sawed-timber prices should decline $20 per thousand board feet below current levels, a timber-lumber mix would provide a greater income than lumber alone.

- Because lumber grades are directly linked to dollar yields, lumbermen want to know the lumber grade volume contained within sawed timbers of various dimensions. This study showed that more than 90 percent of the lumber contained in a 4-by-6-inch timber would grade 2 Common or poorer. In fact, over half the volume was 3 Common regardless of log grade. Even the larger 7-by-9-inch timbers contained 55 to 84 percent of 2 Common and poorer grades. Therefore, only when large timbers are cut from high-grade logs should the millowner expect to enclose significant amounts of high-grade lumber.

- The combined production of lumber and timbers from suitable factory-grade logs will normally increase log overrun, hourly

volume output, and net hourly income. Reduced sawing time per unit of output is a critical factor in affecting the dollar gains achieved from sawed-timber manufacture.

- Hourly log costs increase when timbers are manufactured; but the increase is less for the smaller low-quality logs. However, increased volume and value yields from sawed timbers far outweigh increased raw-material costs.

- Production costs per unit of volume output decrease when timbers are sawed. Large mills have a greater opportunity to reduce production costs because labor and equipment can be manipulated more readily.

- Mill operators who engage in the dual production of lumber and timbers must carefully direct log-bucking and sawing practices to provide maximum income. If logs are bucked to conform to sawed-timber lengths, then potential dollar yields from high-value side lumber are sacrificed because of the preponderance of short boards. Conversely, if logs are bucked to produce long high-grade lumber, then overlength waste blocks from timbers reduce volume yield and dollar income. There is no perfectly satisfactory solution. However, when a sawmill operator has a choice, he should saw timbers from those species and log grades that normally would give him the *lowest* hourly return if sawed exclusively into lumber.

■

APPENDIX

Table 1.—*Lumber grade composition of three sawed-timber sizes, by species and log grade*

(In percent)

Species	Lumber grade	Sawed timber size								
		4 by 6 inches, log grade —			6 by 8 inches, log grade —			7 by 9 inches, log grade —		
		1	2	3[1]	1	2	3[1]	1	2	3[1]
Red oak	FAS-Select	7	—	—	31	11	—	43	15	2
	1 Common	1	6	1	9	19	14	9	25	17
	2 Common	34	36	23	26	33	53	24	36	38
	3 Common[2]	58	58	76	34	37	33	24	24	43
White oak	FAS-Select	1	—	—	3	2	—	11	3	1
	1 Common	3	2	1	7	10	1	12	12	4
	2 Common	13	10	5	30	24	18	31	28	27
	3 Common[2]	83	88	94	60	64	81	46	57	68
Hickory	FAS-Select	7	9	2	27	19	8	39	27	10
	1 Common	3	6	4	15	13	15	16	20	15
	2 Common	72	72	74	42	59	58	37	46	53
	3 Common[2]	18	13	20	16	9	19	8	7	22
Hard maple	FAS-Select	3	7	—	23	10	1	34	11	1
	1 Common	([3])	3	1	7	20	9	15	25	18
	2 Common	40	42	26	41	43	40	31	39	41
	3 Common[2]	57	48	73	29	27	50	20	25	40

[1] Includes tie-and-timber and local-use grades.
[2] 3A and 3B Common.
[3] Less than 1 percent.

Table 2.—*Comparison of cost and value changes when both lumber and lumber plus 7-by-9-inch timbers are sawed from grade 1 maple logs and grade 3 hickory logs*

Item	Grade 1 maple logs		Grade 3 hickory logs	
	All lumber	Lumber and 7-by-9-inch timbers	All lumber	Lumber and 7-by-9-inch timbers
Product volume (board feet):				
Volume in salable lumber	1,595	935	1,552	650
Lumber volume in timbers	—	660	—	902
Overrun from timbers	—	216	—	297
Volume in salable timber	—	876	—	1,199
Total salable volume	1,595	1,811	1,552	1,849
Total product value:				
Value salable lumber	$303.81	$202.91	$128.75	$61.34
Value lumber in timber	—	100.90	—	67.41
Value salable timbers	—	65.76	—	90.05
Value salable lumber and timbers	—	268.67	—	151.39
Value corrected for degrade [1, 2] loss	279.51	263.30	118.47	148.36
Production time (hours):				
All lumber	2.45	—	2.59	—
Lumber in timber	—	0.38	—	0.63
Adjusted time—lumber and timber	—	2.07	—	1.96
Product value per hour	$114.08	$127.19	$ 45.60	$75.81
Costs per hour:				
Log costs	$ 48.42	$ 55.66	$ 18.20	$20.62
Production costs	33.80	33.80	33.80	33.80
Total	82.22	89.46	52.00	54.42
Net value per hour to mill owner (before taxes)	$ 31.86	$ 37.73	$ −6.40	$21.39

[1] Loss in volume and grade due to checking, splitting, shrinkage, and cupping.

[2] Cuppett, Donald G. AIR-DRYING PRACTICES IN THE CENTRAL APPALACHIANS. U.S. Forest Serv. Res. Paper NE-56, NE. Forest Exp. Sta., Upper Darby, Pa., 19 pp. 1966.

Table 3.—*Net hourly income from both lumber and timbers sawed from different species and log grades*

Species	Log grade	Lumber only	Lumber plus timbers measuring—		
			4 by 6 inches	6 by 8 inches	7 by 9 inches
Red oak	1	$25.37	$31.14	$32.20	$34.57
	2	9.30	13.64	17.70	23.17
	[1]3	2.40	6.65	13.60	22.45
White oak	1	13.98	19.55	25.33	29.02
	2	.63	5.58	12.46	19.95
	[1]3	−2.20	.97	11.23	23.89
Hickory	1	12.45	20.89	23.16	27.98
	2	1.94	9.20	15.93	21.50
	[1]3	−6.40	−.68	8.86	21.39
Maple	1	31.86	38.91	39.09	37.73
	2	27.17	34.15	37.08	42.44
	3	18.96	24.93	33.31	36.95

[1] Includes tie-and-timber and local-use grades.

Table 4.—*Physical suitability of red oak logs for the manufacture of sawed timbers*

(In percent)

Log grade	Timber size		
	4 by 6 inches	6 by 8 inches	7 by 9 inches
1	88	90	71
2	88	88	51
[1]3	85	66	41

[1] Includes tie-and-timber and local-use grades.

Table 5.—*Hourly net values obtained from red oak logs*[1] *that were sawed into lumber and timbers at the study mills*

Grade	All lumber	4-by-6-inch timbers and lumber	6-by-8-inch timbers and lumber	7-by-9-inch timbers and lumber
1	$24.53	$29.24	$30.16	$31.20
2	7.86	12.50	14.10	15.21
[2]3	−1.98	3.48	5.62	7.53

[1] All logs were not sawed into timbers.
[2] Includes tie-and-timber and local-use grades.

Table 6.—*Effect of diminishing price levels received for red oak timbers upon the hourly net values received for both lumber and timbers*

Price levels	All lumber	4-by-6-inch timbers and lumber	6-by-8-inch timbers and lumber	7-by-9-inch timbers and lumber
		GRADE 1 LOGS		
I[1]	$24.53	$29.24	$30.16	$31.20
II[2]	24.53	28.15	28.30	28.00
III[3]	24.53	27.05	26.20	25.00
		GRADE 2 LOGS		
I	7.86	12.50	14.10	15.21
II	7.86	9.60	11.06	11.92
III	7.86	7.96	8.30	8.50
		GRADE 3 LOGS[4]		
I	−1.98	3.48	5.62	7.53
II	−1.98	1.43	3.94	5.50
III	−1.98	−.61	2.26	3.46

[1] 4- by 6-, 6- by 8-, and 7- by 9-inch timbers; $60, $65, and $75 per MBF, respectively.
[2] 4- by 6-, 6- by 8-, and 7- by 9-inch timbers; $50, $55, and $65 per MBF, respectively.
[3] 4- by 6-, 6- by 8-, and 7- by 9-inch timbers; $40, $45, and $55 per MBF, respectively.
[4] Includes tie-and-timber and local-use grades.

Table 7.—*Lumber prices per thousand board feet*[1] *received by study mills*

Species	Lumber grade				
	FAS	Select	1 Common	2 Common	3 Common [2]
Red oak	$200	$190	$130	$80	$70
White oak	210	200	130	80	70
Hickory	160	150	140	50	50
Maple	250	230	200	85	70

[1] Prices f.o.b. mill yard.
[2] Price weighted by relative volumes of 3A and 3B Common produced.

Table 8.—*Negotiated prices per thousand board feet*[1] *at mills studied for manufactured ties and timbers*

Species[2]	Timber size		
	4 by 6 inches	6 by 8 inches	7 by 9 inches
Red oak	$60	$65	$75
White oak	60	65	75
Hickory	60	65	75
Maple	60	65	75

[1] F.o.b. mill yard.
[2] No price difference existed for the species studied.

Table 9.—*Log costs per thousand board feet,*[1] *f.o.b. yards at study mills*

Species	Log grade		
	1	2	3[2]
Red oak	$65	$50	$40
White oak	60	50	40
Hickory	60	50	40
Maple	70	50	40

[1] Doyle scale.
[2] Includes tie-and-timber and local-use grades.

Table 10.—*Hourly mill and yard costs for the study mills*

MILL COSTS:	
Labor	$ 6.20
Supplies and expenses	1.95
Group insurance, payroll taxes, and compensation	.95
Depreciation expense	3.85
Fire insurance	.47
Interest on debt:	
Capital investment	2.25
Borrowed operating income	1.15
Total mill costs per hour	$16.82
YARD COSTS:	
Labor (includes mill manager)	6.40
Supplies and miscellaneous expenses	3.10
Group insurance, payroll taxes, and compensation	1.05
Depreciation expense	1.85
Fire insurance	1.38
Administration expense (sales, accounting)	3.20
Total yard costs per hour	16.98
Total production costs per hour (excluding log costs)	33.80

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